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Acoustic Monitoring Report, Noatak National Preserve – 2013 and 2014

Natural Resource Data Series NPS/NOAT/NRDS—2015/787

ON THE COVER
The Noatak River shines on a rainy afternoon in Noatak National Preserve.
NPS Photo by Andrew Ackerman

Acoustic Monitoring Report, Noatak National Preserve – 2013 and 2014

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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Executive Summary

In 2009, natural soundscapes were recognized as a fundamental resource of Noatak National Preserve in their foundation statement (NPS 2009). In 2013 and 2014, NPS staff deployed acoustic monitoring systems to a total of four locations across Noatak National Preserve. The goal of this effort was to measure baseline natural sound conditions and to collect data on overflight and river boat activity during the hunting season. This effort is one component of a larger, integrated, multi-phase research effort by Western Arctic Parklands (WEAR) staff. The effort seeks to further understand fall caribou hunting conflict between local subsistence and non-local hunters in Noatak. These acoustic data add to research conducted from 1988 through present by the National Park Service (NPS), State of Alaska (SOA), and the academic community.

Data collected included sound pressure levels every second and continuous MP3 audio recordings throughout the sampling period. These data serve as a permanent record of existing acoustical conditions at select locations during the hunting seasons of 2013 and 2014.

During hunting season the average aircraft noise events per day ranged from 3.7 events per day at Kugururok River (2014) to 7.8 events per day at Sapun Creek (2014). Note that these two sites were deployed over the same time period and on the same river (Noatak), but the site 57 miles farther east had over twice the number of aircraft noise events. Whether this is the result of the NPS delayed-entry area and Alaska Department of Fish & Game (ADFG) Controlled-use Area (CUA) covering areas to the west of Sapun or due to the recent easterly trend of the primary migration routes of the Western Arctic caribou herd (Joly, 2014) cannot be determined from the data that were collected during this study. However, it is clear that propeller aircraft noise differs between the two sites at this time of the year.

Conversely, and as expected, watercraft were less commonly detected on the eastern portions of the Noatak. At the Kugururok River site, 40 miles from the Village of Noatak, motorboats were detected at an average of 5.1 events per day. Another 57 river miles upstream at Sapun Creek (2014), there was less than one third the observed boat traffic - 1.4 events per day. Again, it cannot be determined from this study whether this is an effect of management action or simply due to the physical and economic constraints of water travel.

Typical maximum sound pressure levels differed between aircraft and watercraft. At sites where boats passed nearby (Kugururuok 2014, Sapun Creek 2014,) median levels were comparable to aircraft. Median sound pressure levels for aircraft were always in the 40 – 50 dBA range, with a louder subset was always observed between 60 and 80 dBA. By comparison, the loudest level observed for boats at any site was less than 60 dBA. Furthermore, takeoffs at Agashashok River (2013) and Sapun Creek (2014), with maximum sound pressure levels at or above 100 dBA. (Figure 8, Figure 26.)

On the other hand, Noatak is among the rare park units that have minimal noise intrusions from jet aircraft. For example, a single jet noise event was detected at Kugururok River (2013) over the course of the 12 day sampling period. This is in direct contrast with parks in the contiguous United

States, where jet traffic is the most widespread source of noise. (Lynch 2011) Thus, during times when fixed-wing aircraft use is low, the preserve is likely to have natural quiet of a condition unmatched by any parks but its Alaskan relatives.

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Introduction

Of all the units in the national park system, Noatak National Preserve is among the largest, wildest, and most free of human influences and intrusions (NPS 2009). Noatak is one of four NPS units managed by Western Arctic National Parklands (WEAR), with headquarters in Kotzebue, Alaska. Noatak's Foundation Statement, finalized in 2009, interprets the preserve's establishing legislation, ANILCA Section 201. The act called for the preserve to be managed "to maintain the environmental integrity of the Noatak River and adjacent uplands within the preserve in such a manner as to assure the continuation of geological and biological processes unimpaired by adverse human activity." In the foundation statement, the natural acoustic environment is specifically described as one of five fundamental resources of the arctic wilderness across the Preserve. This report details the first attempts by WEAR to inventory the acoustic environment of the Noatak River basin via a system of automated measurements. Acoustic measurements are objective, continuous, spatially explicit, and employ monitoring methods easily reviewed by the public. Before this point, Noatak managers had limited information about the acoustic environment of the preserve during hunting season. These data can be useful in developing management guidelines or to garner support for management decisions that may affect the quality of Noatak's natural soundscape.

The initial push for soundscape inventories on NPS managed lands began with Director's Order 47 (DO-47; NPS 2000). Robert Stanton issued the order in 2000 directing park managers to identify baseline soundscapes and related measures. DO-47 states that "natural sounds are intrinsic elements of the environment that are often associated with parks and park purposes…They are inherent components of 'the scenery and the natural and historic objects and the wild life' protected by the NPS Organic Act." DO-47 directed park managers to "(1) measure baseline acoustic conditions, (2) determine which existing or proposed human-made sounds are consistent with park purposes, (3) set acoustic management goals and objectives based on those purposes, and (4) determine which noise sources are impacting the park and need to be addressed by management." Furthermore, it requires park managers to "(1) evaluate and address self-generated noise, and (2) constructively engage with those responsible for other noise sources that impact parks to explore what can be done to better protect parks." (NPS 2000).

Soundscape Planning Authorities

The National Park Service (NPS) Organic Act of 1916 states that the purpose of national parks is "… to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (NPS 1916) In addition to the NPS Organic Act, the Redwoods Act of 1978 affirmed that, "the protection, management, and administration of these areas shall be conducted in light of the high value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." (NPS 1978)

[1]Direction for management of natural soundscapes[1] is represented in 2006 Management Policy 4.9:

> "The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts. Using appropriate management planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of acceptable levels of unnatural sound will vary throughout a park, being generally greater in developed areas. In and adjacent to parks, the Service will monitor human activities that generate noise that adversely affects park soundscapes [acoustic resources], including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape [acoustic resource] or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored" (NPS 2006a)."

It should be noted that the Management Policy 8.2.3: Use of Motorized Equipment states "the natural ambient sound level—that is, the environment of sound that exists in the absence of human-caused noise—is the baseline condition, and the standard against which current conditions in a soundscape [acoustic resource] will be measured and evaluated" (NPS 2006b). However, the desired acoustic condition may also depend upon the resources and the values of the park. For instance, "culturally appropriate sounds are important elements of the national park experience in many parks" (NPS 2006b). In this case, "the Service will preserve soundscape resources and values of the parks to the greatest extent possible to protect opportunities for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (NPS 2006b).

History of Managing Aircraft in Noatak Preserve

The first priorities for this acoustic monitoring were guided by the Preserve's history of fall caribou hunting conflict between local subsistence and non-local hunters. In brief, the sudden onset of non-local hunting in and around the preserve in the 1980s resulted in competition for the fall-season migrating Western Arctic caribou herd. Such competition caused tensions to develop between local and non-local hunters. Over the last few decades non-local caribou hunting, and associated transporter flights, have remained stable or increased, with the majority of increase likely occurring from 2000 – 2010 (Ackerman, 2013). Acoustic data collection is one component of a larger, integrated, multi-phase research effort by WEAR staff to study the user conflict issue in Noatak. WEAR Resources staff collaborated with the author to develop the research design and plan field logistics. Prior to the current research effort, federal and state resource staff have utilized surveys,

[1] The 2006 Management Policy 4.9 and related documents refer to "soundscapes" instead of "acoustic resources." When quoting from this authority, it is advisable to note that the term often refers to resources rather than visitor perceptions.

village focus groups, and a combination of observational methods aimed at understanding particular aspects of the fall caribou hunting effort. These efforts resulted in preliminary descriptions of transporter overflights and local boat traffic rates, use patterns, and perceived conflicts or value differences between locals and non-local hunters in the Noatak region. The reader is encouraged to learn more about this history in any of various papers on the topic including - Georgette and Loon 1988, Hunt and Hollingsworth 1996, Jacobson 2008, and Fix and Harrington, 2009. Local subsistence users primarily use boats to hunt in the preserve, while non-locals primarily use aircraft. Because of this, a trend of increasing aircraft noise was specifically recognized by locals as a concern for potential effects on success of water-based caribou hunters. To address this concern, the Alaska Board of Game (BOG) implemented the Noatak Controlled Use Area in 1988.

Currently, the Alaska Department of Fish and Game (ADFG), Game Management Unit 23 (GMU 23) Noatak Controlled Use Area (CUA; 5AAC § 92.540) consists of "that portion of Unit 23 in a corridor extending five miles on either side of, and including the Noatak River, beginning at the mouth of the Noatak River, and extending upstream to the mouth of Sapun Creek." (See Figure 1.) Approximately 80 of the 160 plus river miles affected by the CUA are within the western portion of Noatak National Preserve. The Noatak CUA "is closed from August 15 through September 30 to the use of aircraft in any manner for big game hunting, including the transportation of big game hunters, their hunting gear, or parts of big game; however, this provision does not apply to the transportation of big game hunters, their hunting gear, or parts of big game to and between publicly owned airports. Pilots and passengers not hunting big game may utilize the CUA for other purposes. The big game species affected by the Noatak CUA include: bear (brown or black), caribou, moose, muskox, sheep, wolf and wolverine. Aircraft access is only allowable to and from the state-maintained airport at the village of Noatak when hunting these species. During the aircraft closure period, hunters can fly into or out of the Noatak airport then access the CUA by any means other than aircraft."

The Alaska Administrative Code also details hunter education requirements for any pilot in Unit 23 (Noatak Preserve is completely contained within Unit 23) transporting big game from the field. (5 A.A.C. § 92.003) In GMU 23, "a pilot may not transport parts of big game with an aircraft without having, in actual possession, a certificate of successful completion of a department-approved education course regarding big game hunting and meat transportation in this unit. The provisions of this section do not apply to the transportation of parts of big game between state maintained airports." The ADFG GMU 23 aircraft use education course suggests that pilots, "should maintain a minimum altitude of two thousand (2000) feet in the vicinity of [camps and residential properties] unless required by weather, emergencies, or if taking off or landing." Furthermore, they are "advised to not take off, land or drop off clients within 1.5 miles of other camps or on lakes where camps are already established. The permittee is encouraged to notify adjacent camps of activities to reduce potential user conflicts." (Alaska Department of Fish and Game, 2015.)

In addition to these state actions, the National Park Service also responded to the user conflict with management action. From 2008 to 2009, Noatak Preserve managers experimented with capping the number of authorized commercial transporters as well as the total number of clients. These actions were abandoned in 2012 as, "restricting transporter activities without adequately addressing user

conflicts." At that time NPS managers decided instead to expand the areas closed to big game transporter access. The following language, generally described as the 'Transporter Delayed Entry Area,' is now a stipulation of commercial use permits for air taxis and big game transporter services in the Noatak Preserve. It states, "Commercial Transporter Visitor Services CUA holders will be authorized to transport non-federally qualified (i.e., non-local) caribou hunters into the area west of the Kugururok River and Maiyumerak Mountains after September 15th, unless authorized by the superintendent to provide services before September 15th."

The delayed entry area extends the full north-south distance of the preserve, including approximately 25 miles of the Noatak River (where it overlaps the ADFG Noatak CUA). The total area of the closure is just over 2,000 sq. miles. (See Figure 1.) The area is closed from January 1st until September 15th each year. During that time period it acts to spatially separate non-local, commercially transported caribou hunters from local subsistence hunters travelling along the Noatak River and lower reaches of major tributaries of the Noatak, such as the Agashashok, Eli, Kugururok, and Kelly River. Unlike the ADFG Noatak CUA, the NPS closure only affects non-local caribou hunters and non-local hunters being commercially transported. Non-local hunters arriving via their own personal aircraft or in pursuit of moose, sheep, or any big game other than caribou, are unaffected by the NPS closure.

Study Area

NPS staff deployed acoustic monitoring systems to a total of four locations across Noatak National Preserve in 2013 and 2014, as shown in Table 1 and Figure 1. However, only three of the sampling locations collected usable data.

Sample design resulted from a review of administrative history, prior-year transporter activity, and a variety of constraints on field logistics. It was recognized by park staff that five basic categories of aircraft management were in place: 1) areas affected by the NPS delayed entry area only, 2) areas affected by the state controlled use area only, 3) areas affected by both the NPS and State management areas, 4) areas unaffected by aircraft management practices, and 5) areas inside and outside the federally designated Wilderness portions of the preserve. Thus, at least one sampling location was selected from each of the areas during the initial effort. Access via fixed-wing, wheeled aircraft further limited sites to areas near airstrips or river bars where landings could be conducted safely.

Table 1. Sites sampled in 2013, 2014.

Site Location	Year(s)	Elevation (m)	Latitude	Longitude	Days Sampled	Wilderness	Aircraft Management
Agashashok River	2013	89	67.47208	-162.22423	44	No	NPS CUA only
Kugururok River	2013, 2014	84	67.97138	-161.93248	12,19	Yes	NPS and State CUAs
Sapun Creek	2013^, 2014	160	67.89567	-160.35813	NA,19	Yes	No restrictions (but only 1500m east of State CUA)
Cutler River	2013^	463	67.66269	-158.17857	NA	Yes	No restrictions

* One month of continuous data is the sampling goal, but some sites do not achieve this goal due to equipment failure, animal disturbance, insufficient solar radiation, or access scheduling. An acoustic profile was compiled using the available data.

^ Indicates the station failed during the given year. Due to remoteness, Cutler River was not resampled in 2014.

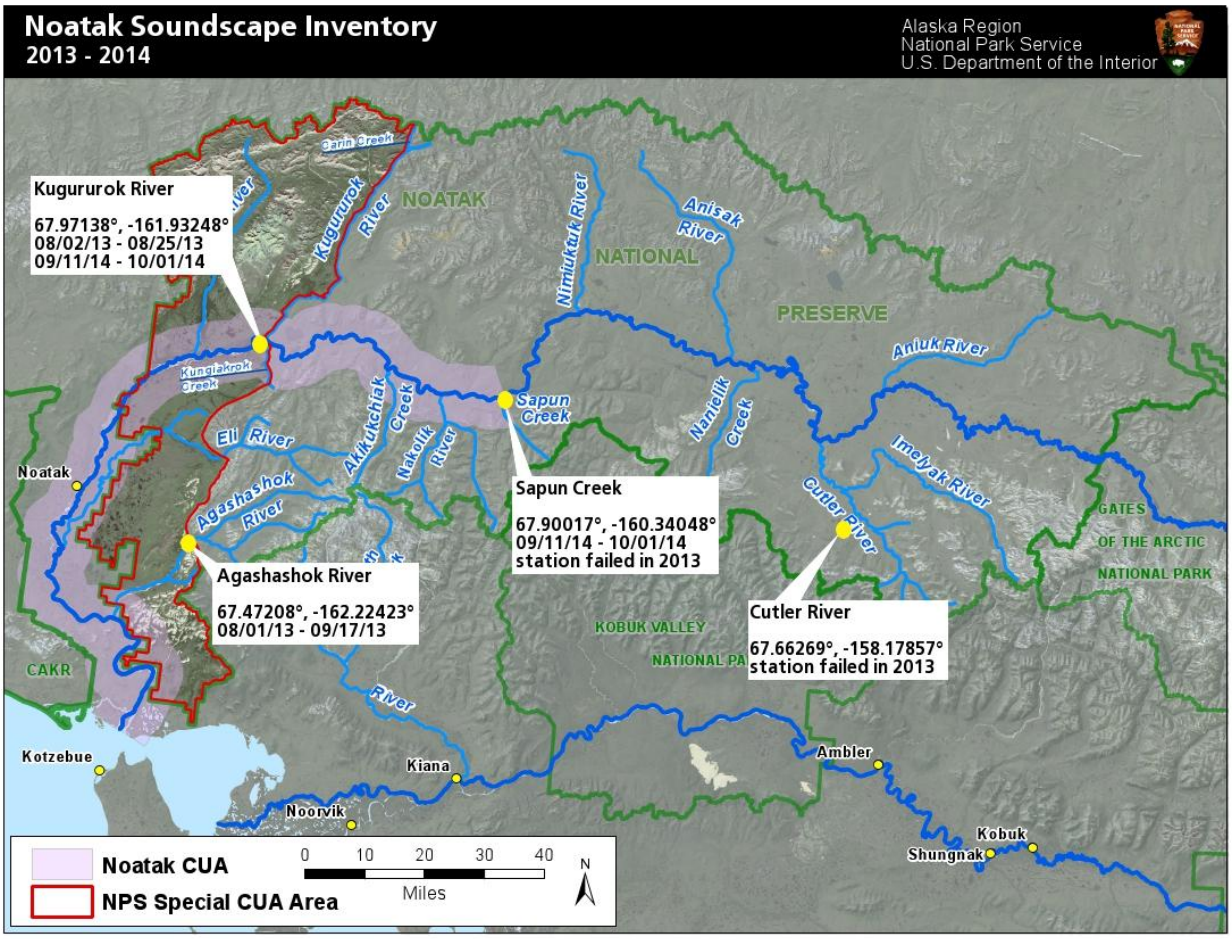


Figure 1. Acoustic monitoring sites in Noatak National Preserve during the fall of 2013 and 2014. Local villages and rivers are shown for context, as are the NPS and State of Alaska controlled use areas.

Methods

Automated Monitoring

The Larson Davis 831 sound level meter (SLM) is a hardware-based, real-time analyzer which constantly records one-second sound pressure level (SPL) and 1/3 octave band data, and exports these data to a USB storage device. These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards (ANSI 1968, 1992). To supplement the SPL data, Roland R-05 field recorders capture 64kbps mp3 recordings via the Larson Davis 831 audio output.

Each Larson Davis sampling station consists of:

- Microphone with environmental shroud and windscreen
- Preamplifier
- Roland R05 mp3 recorder
- Solar panel and batteries
- Anemometer/Wind Vane/Temperature and Relative Humidity Probe

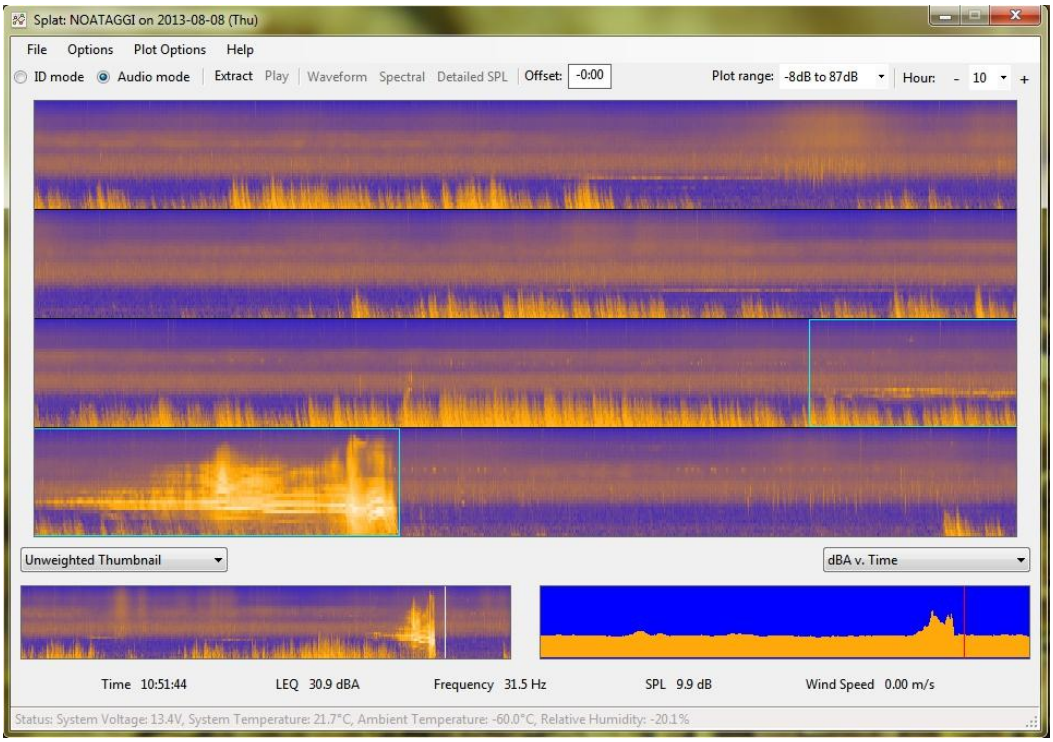
Each station collected:

- SPL data in the form of A-weighted decibel readings (dBA) every second
- 1/3 octave band data every second ranging from 12.5 Hz – 20,000 Hz
- Continuous 64 kilobit-per-second digital audio recordings

Visual Analysis of Spectrograms

For each monitoring site, staff visually analyzed SPL samples of the acoustic record to identify the frequency and durations of mechanized sound sources. Hourly time audible statistics are then used to calculate natural ambient sound level estimates.

Sound pressure levels (SPL) from one hour at an acoustic monitoring site at Noatak National Preserve are shown in the image below. One hour of SPL data is displayed over four rows. Each row shows SPL values from low frequency (12.5 Hz, bottom of line) to high frequency (20 kHz, top of line). Values are represented with a color scale, where dark blue is quiet and yellow/white is loud. Thus, individual events stand out against the blue background, appearing as yellow areas.



Acoustic events can be visually identified (by drawing a box around the event) and annotated. For each identified event, time, duration, maximum SPL, and spectral information are cataloged. For example, the blue box above marks fixed-wing landing.

Audibility Analysis

For each monitoring site, staff analyzed a subset of the audio record— the first five seconds of every five minute interval of the day, starting at 00:00. The purpose of the analyses was to identify natural and quiet sound sources which are difficult to reliably identify through visual analysis. Listening headphones were calibrated with a 94 dB, 1000 Hz tone which was recorded at the time of data collection. This approximates a playback volume similar to what would be heard if the observer were actually listening at the sample site. These audibility data result in an estimate of total percent time audible and makeup of the natural and anthropogenic components of the soundscape.

Calculation of Metrics

Several metrics are calculated to provide some detail about the characteristics of the acoustical environment. These include sound pressure levels for each 1/3 octave band from 12.5 Hz to 20,000 Hz, overall broad-band sound pressure levels, and percent time audible for various sound sources. Two fundamental descriptors of the acoustic environment are: existing ambient and natural ambient sound levels which are presented as exceedence levels (L_x). Equivalent to percentiles, exceedence levels represent the dBA exceeded x percent of the time for each hour of the day during the given measurement period. For example, measured in dBA, the existing ambient (L_{50}) is the sound level exceeded 50% of the time, or median sound level, for each hour of the day and averaged over the sample period. Existing ambient is the uncensored composite of all sounds at a site, both human caused and natural. The natural ambient (L_{nat}) estimates the acoustic environment without the

contribution of anthropogenic sounds. L_{10} and L_{90} are also presented which describe the sound levels exceeded 10% and 90% of the time, respectively.

The differences between L_{50} and L_{nat} values allow NPS to answer the following questions:

1. What are the listening opportunities in the absence of noise from human development and activities?
2. How are these listening opportunities compromised by increased sound levels due to extrinsic noise?

To calculate L_{nat}, the following method is utilized:

- NPS staff calculates the proportion, P_H, of all samples containing extrinsic sounds for each hour of the day both by listening to samples, or visually analyzing daily spectrograms.
- P_H is used to complete this formula for every hour in the dataset: $x = \frac{1 - P_H}{2} + P_H$
- Hourly x_H values are entered into a database of all octave band information.
- Example: if extrinsic sounds are audible 50% of the time (P_H =0.5), then x_H is 0.75.
- L_{nat} is computed as the sound level that is exceeded 100*x_H percent of the time.
- (In practice, L_{nat} is calculated by sorting the relevant sound level measurements and using x_H to extract the appropriate order statistic).

This procedure approximates the sound levels that would have been measured in the absence of extrinsic noise. The procedure is guaranteed to produce an estimate that is equal to or below the existing ambient sound levels, and the results of this calculation have produced consistent results at most backcountry sites analyzed by the NPS Natural Sounds Program (Lynch et al. 2011).

Results

The following tables are summaries of the 2013-2014 data. The existing and natural ambient sound statistics are presented in A-weighted decibels, average percentage of time audible, number of events per day, and maximum sound pressure level for aircraft (in Table 2) and other motorized sound sources (in Table 3). The 24-hour average noise-free interval describes the typical amount of time *between* motorized events throughout the entire day. The median existing ambient level (L_{50}) describes the typical acoustic environment as it is directly observed, including both natural and anthropogenic sounds. Natural ambient (L_{nat}) estimates the magnitude of acoustic energy at the location without the contribution of anthropogenic sounds. This table also shows exceedence metrics L_{10} and L_{90}, which mark the 90^{th} and 10^{th} percentiles of sound pressure level, respectively. These metrics help to demonstrate the high and low bounds of the total acoustic environment as it changes throughout the sample period.

When interpreting sound pressure level (SPL) data, it should be noted that the decibel scale is logarithmic. As such, a six decibel increase in sound pressure level is a doubling of sound pressure. (Sound pressure can be conceptualized as the amount of force applied to a unit area or the amount of energy contained within a unit volume.)

Table 2. Median natural and existing ambient sound levels and mean aircraft statistics for all sites.

Site Name	Year	L10*	Lnat*	L50*	L90*	Avg. Noise Free Interval*	% Time Audible, Aircraft	# Aircraft/ Day	Median Aircraft Max SPL*
Agashashok River	2013	31.8	30.3	30.5	30.2	3.48	2.47	6.7	42.8
Kugururok River	2013	33.8	26.3	26.3	22.7	7.68	1.82	4.2	45.6
Kugururok River	2014	32.0	29.2	29.4	27.5	2.70	1.76	3.7	43.8
Sapun Creek	2014	33.2	28.6	28.7	25.9	2.59	2.87	7.8	48.0

*L_{nat}, L_{10}, L_{50}, L_{90}, and SPL in dBA. Noise-Free Interval in hours.

Table 3. Mean statistics* for watercraft at all sites.

Site Name	Year	% Time Audible, Boats	# Boat Events / Day	Median Boat Max SPL
Agashashok River	2013	0.57%	0.1	32.3
Kugururok River	2013	0.00%	0	*Not Applicable*
Kugururok River	2014	3.20%	5.1	45.4
Sapun Creek	2014	0.96%	1.4	42.4

*SPL in dBA.

Data collection was attempted on the Cutler River in 2013. Due to electrical issues during installation, the station failed shortly after being deployed. The several hours of data that were collected do not cover the range of variability in acoustic conditions likely experienced at this location, which are influenced by wind, cloud cover, flight schedules, or ambient temperature. Data collection was also attempted on Sapun Creek in 2013, but the equipment was never recovered. During the spring flooding it was likely carried away by the Noatak River, and all data, if any, were lost.

The following summaries and figures represent the reduced data for each of the sites that collected data in 2013 and 2014. These include percent audibility for natural sounds and mechanized noise, temporal audibility of sources, hourly natural ambient and exceedence sound levels, percentage of time audible, number of events per day, and maximum sound pressure level by source type.

Agashashok River, 2013

Location Description: Located to the southeast of the main channel of the Agashashok River by about 150 meters.

Purpose/Project: The purpose of this project was to collect preliminary natural soundscape data in Noatak National Preserve, and to quantify the acoustic impact of both aircraft and motorboats in an area within the NPS delayed-entry area but not affected by the ADF&G controlled-use area or Wilderness designation. By placing this monitor on the eastern boundary of the delay-entry area it can indicate what conditions are like in transition zones between the delay-entry area to areas to the east that do not have aircraft landing limitations.

Coordinates: 67.47208°, -162.22423° (WGS84)

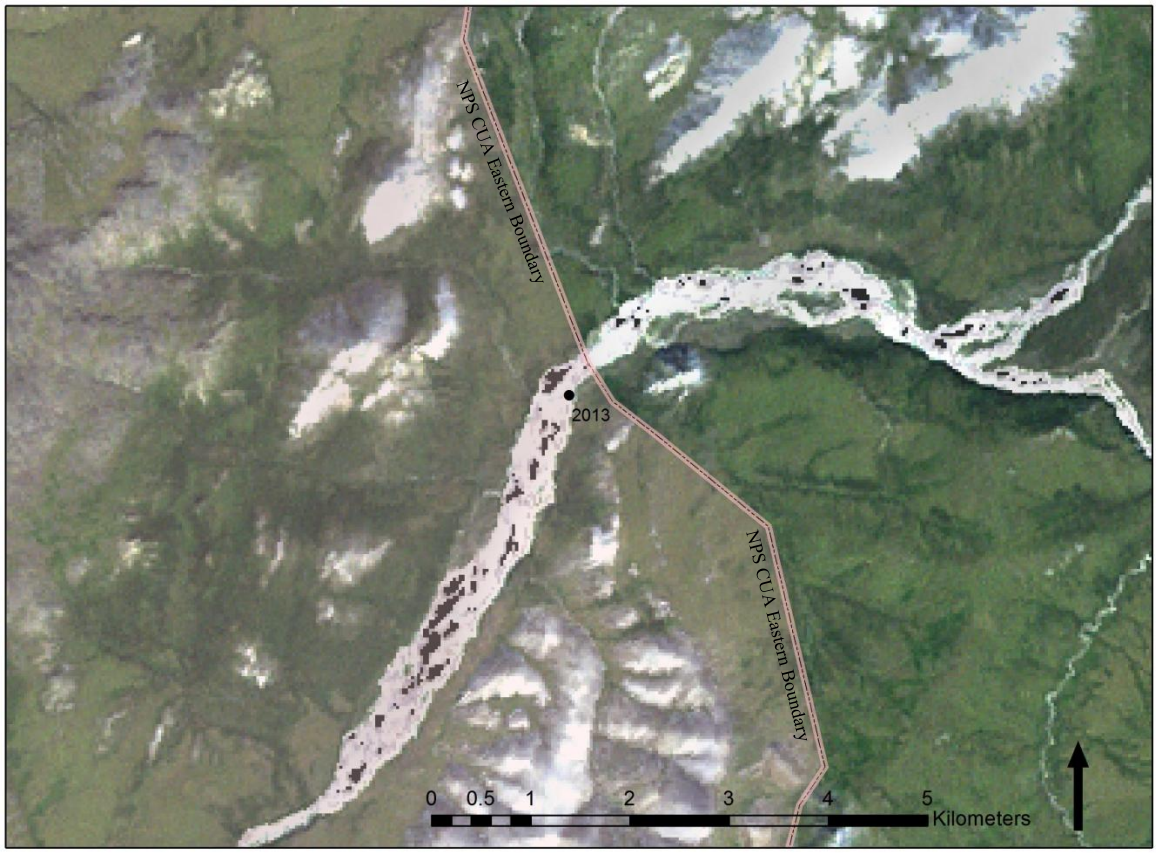
Elevation: 89 meters

Sampling Period: 01-August-2013 to 17-September-2013

Backcountry Management Area: On the eastern boundary of the NPS delayed-entry area in the southwestern portion of the preserve. Non-Wilderness area.

Ecotypes: Low Shrub Birch / Ericaceous / Willow, Sparse Vegetation

Access: Cessna 206 on wheels. Curtis Cebulski pilot, Andrew Ackerman and Marci Johnson technicians.



Summary: The riparian soundscape in the vicinity of the Agashashok River had a time-averaged natural ambient level of 30.3 dBA. Proximity to energetic water made the ambience somewhat time-invariant, as can be seen in Figure 3. There is, however, a noticeable decrease in levels starting around the 06:00 hour towards 10:00, which is the quietest time of a typical day. This diurnal decrease in sound pressure levels is likely due to a change in the refractive index of the atmosphere. Such soundscapes are typical of riparian areas - where a continuous sound source predominates - and has been observed elsewhere in the state. (Betchkal 2013, pg. 60.)

Human-caused noise was audible for 2.50% of a typical day, or about 36 minutes. Particularly notable at the Agashashok River site were a large number of fixed-wing takeoffs and landings. The station recorded 23 landings and 21 takeoffs during the 44 day sampling period, averaging to 1.0 per day. These localized operations make up approximately 15% of the 6.7 aircraft-related noise events observed on a typical day. Maximum sound pressure levels of takeoffs often registered over 100 dBA at the site location (see Figure 8). Most landings, and sometimes takeoffs, would circle the area several times before setting down, as is customary for unimproved landing strips. The large sample of takeoffs and landings and the finding by A. Ackerman (NPS, personal communication, August 1, 2013) that this specific group of hunters were using their own personal aircraft, make this dataset valuable for insights into daily use patterns of non-commercial caribou hunting aircraft operating in Noatak Preserve. For more information on the timing of takeoffs and landings, see Figure 2.

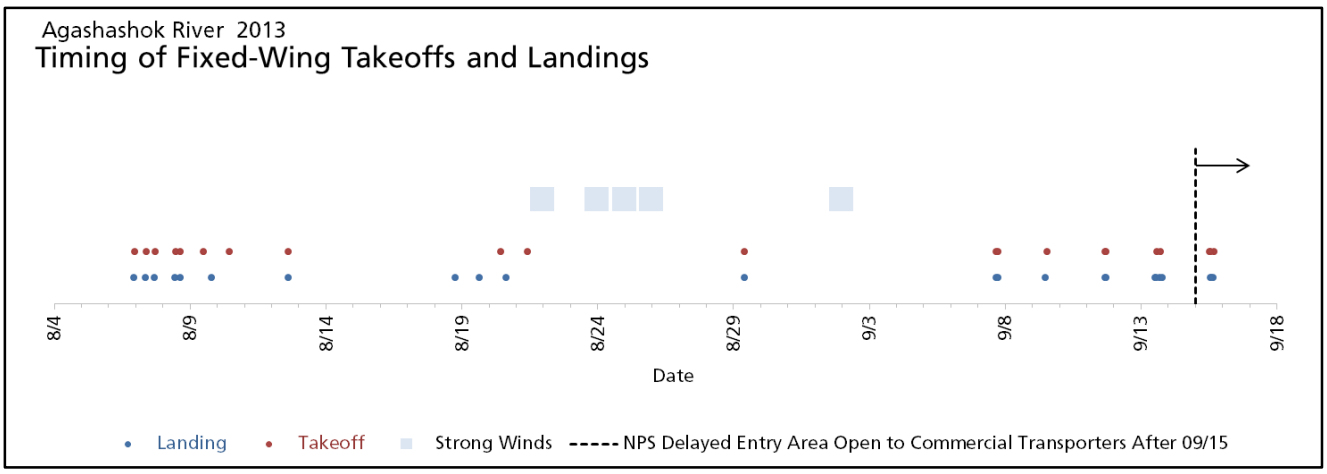
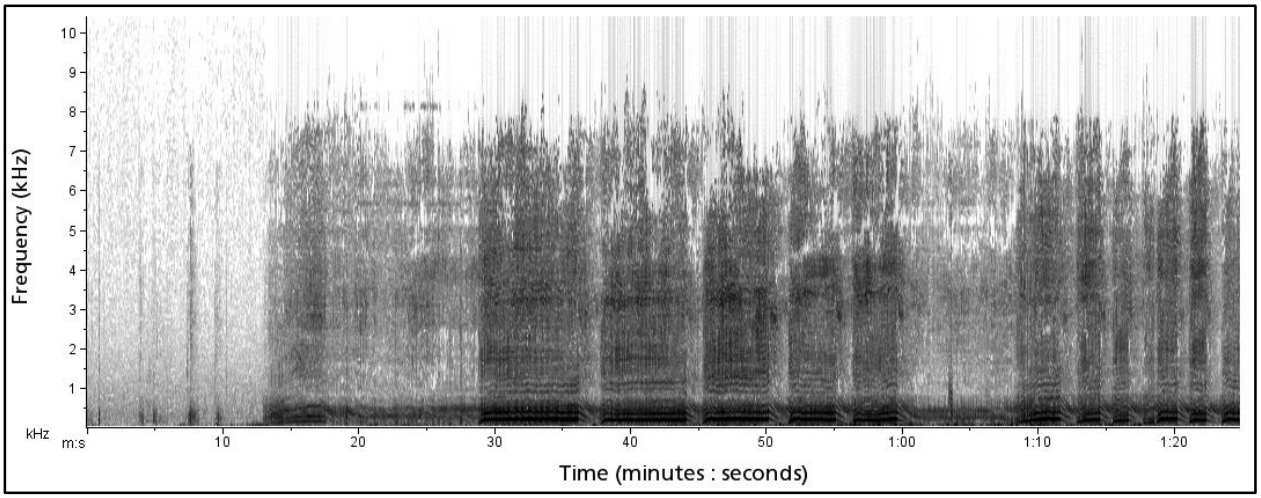


Figure 2. Timing of Takeoff and Landing Events at Agashashok River. Also annotated are periods of strong wind. Note that the NPS Delayed Entry Area is closed to commercial big game transporters from January 1st to September 15th.

A hunting camp was made approximately 100 yards from the sound station for a portion of the sampling period. Human voices were often heard, and several individuals approached the station, contemplating its function. Hunters in this camp regularly employed the use of chainsaws on several separate sequences of days. Most of the use was in short bursts of work lasting 3 to 4 minutes, but occasionally lasted up to 20 minutes at a time. The median level of chainsaws at their loudest was 54.1 dBA.



Spectrogram 1. A reference spectrogram of a chainsaw in operation near the Agashashok River site. Note that the event continues past the end of the spectrogram. Darker portions indicate times when the saw was being used to cut. The clip begins at 18:43:44 on 08/08/2013.

Motorboats were limited to three events early in the morning hours. These were likely detected only due to refractive effects in the atmosphere – which can cause sound to bend, thus making distant noise sources audible where they normally would not be heard. In total, boats were only audible for

0.57% of the sampling period, or about 16 minutes in total. The level for all three boat events was close to the natural ambient level.

The most prominent natural sound sources at the Agashashok River site were abiotic, with flowing water and wind both audible for a large part of the sampling period. Biotically, commonly detected species included White-crowned Sparrow (*Zonotrichia leucophrys*), Grey Jay (*Perisoreus canadensis*), Redpoll (*Acanthis spp.*), Northern Raven (*Corvus corax*), and Tree Swallow (*Tachycineta bicolor*).

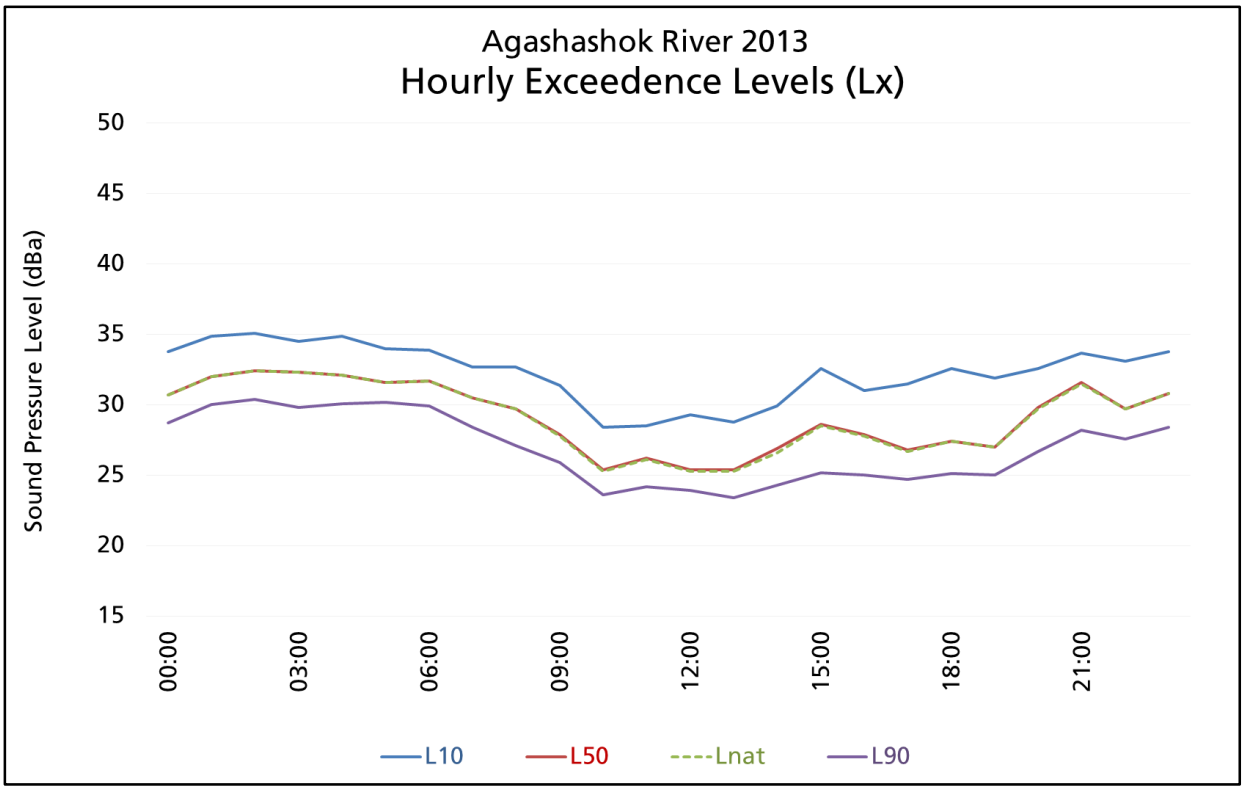


Figure 3. Exceedence levels for Agashashok River, 2013.

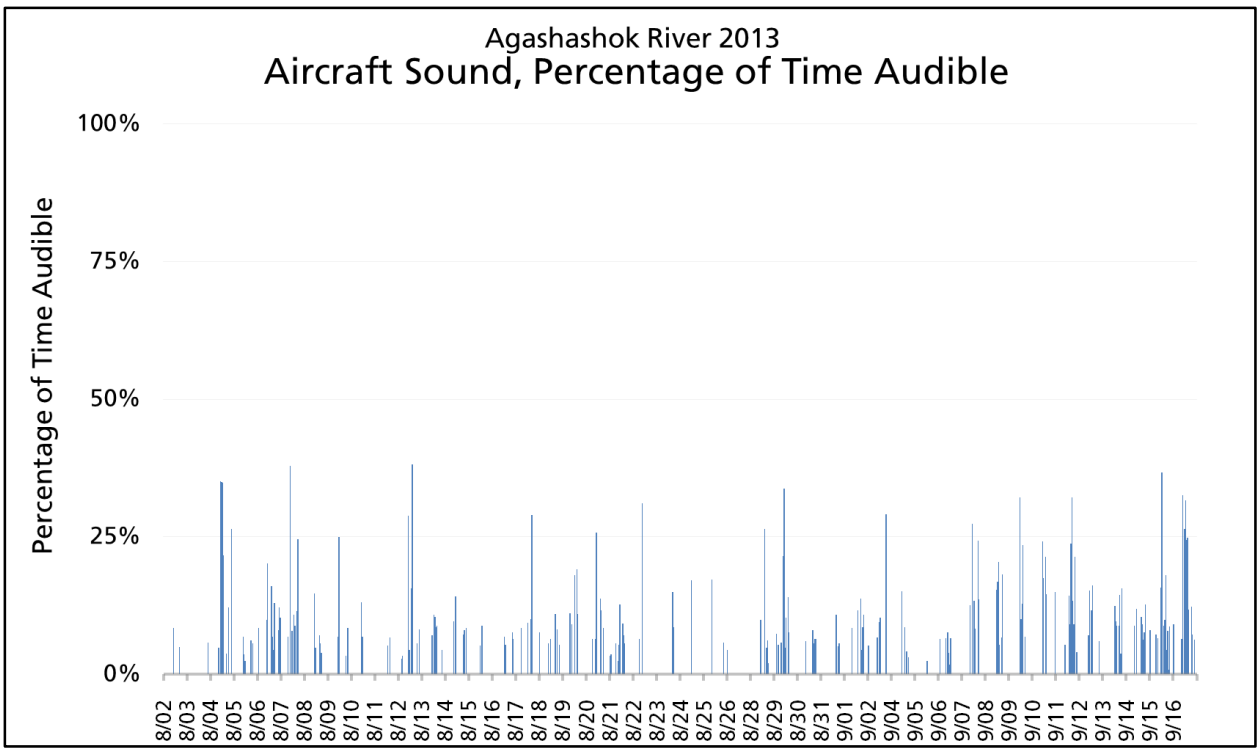


Figure 4. Audibility of aircraft noise at Agashashok River, 2013.

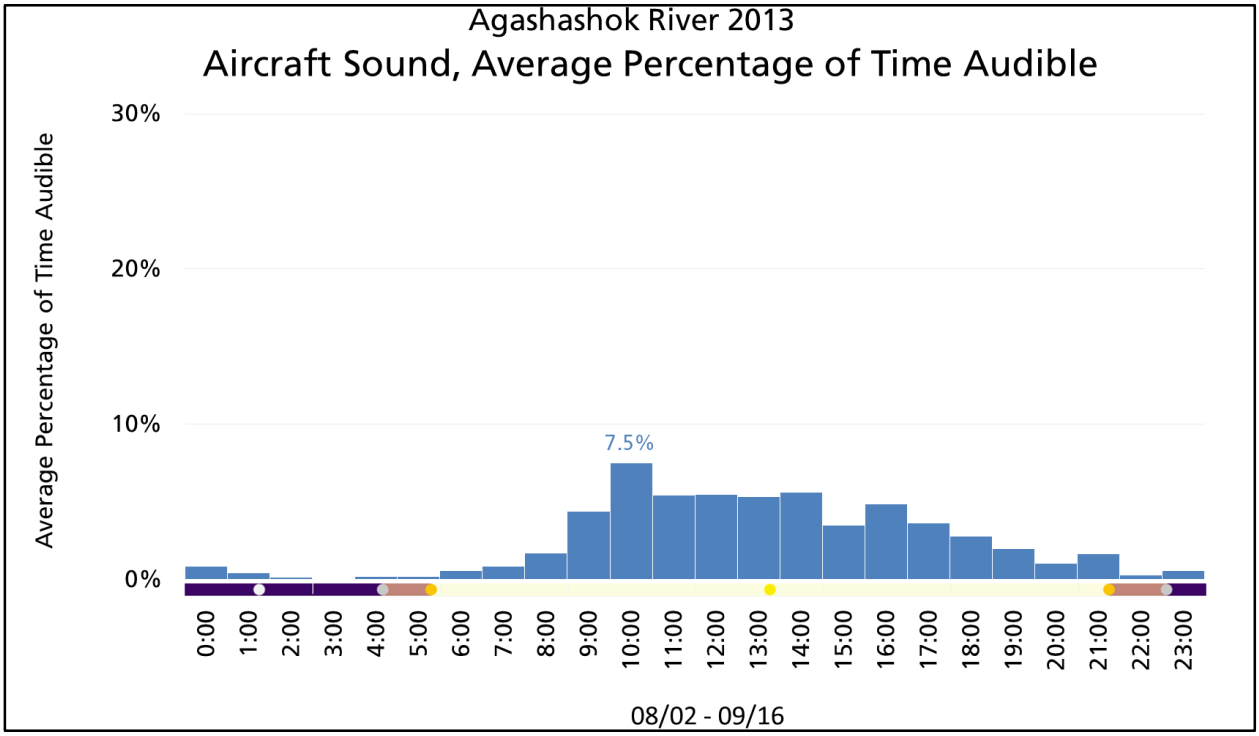


Figure 5. Audibility of aircraft noise for an average day, by hour, at Agashashok River, 2013. The bar along the time axis indicates the average light conditions during the sampling period. The orange circles are sunrise/sunset, and the gray circles are the beginning and end of civil twilight.

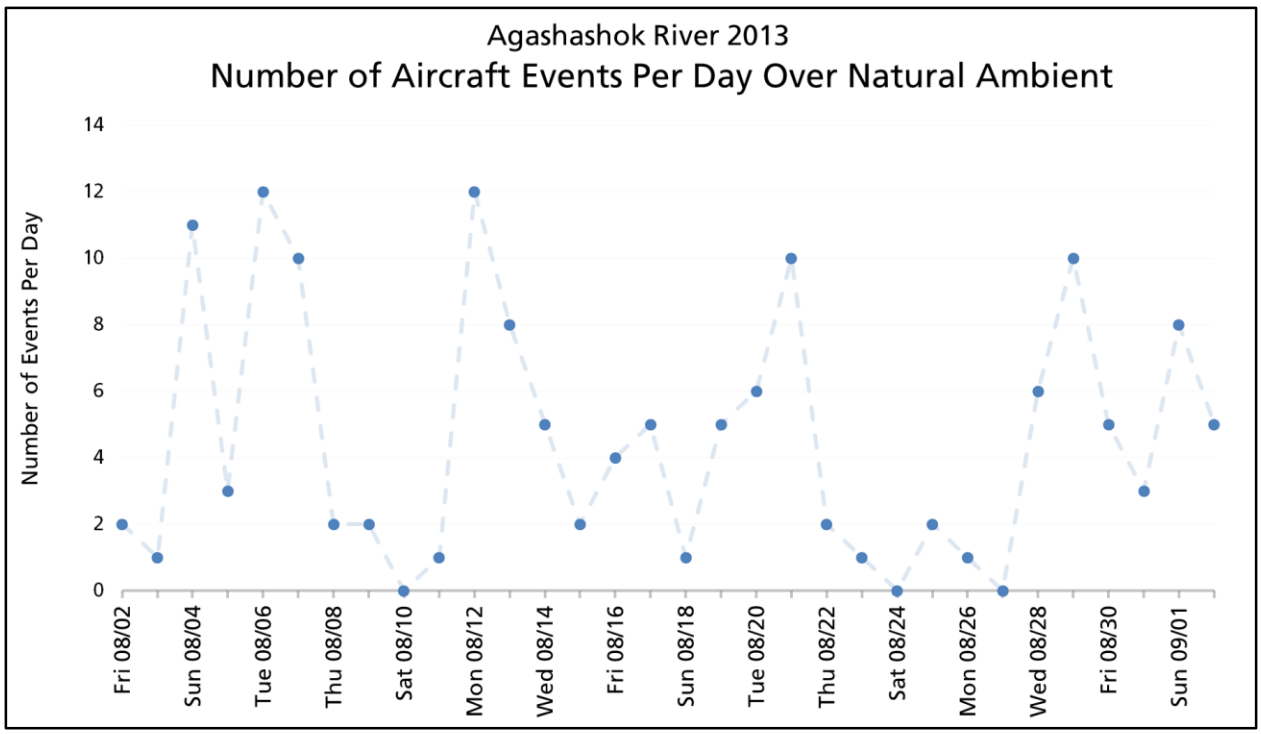


Figure 6. Number of aircraft noise events detected per day at Agashashok River, 2013.

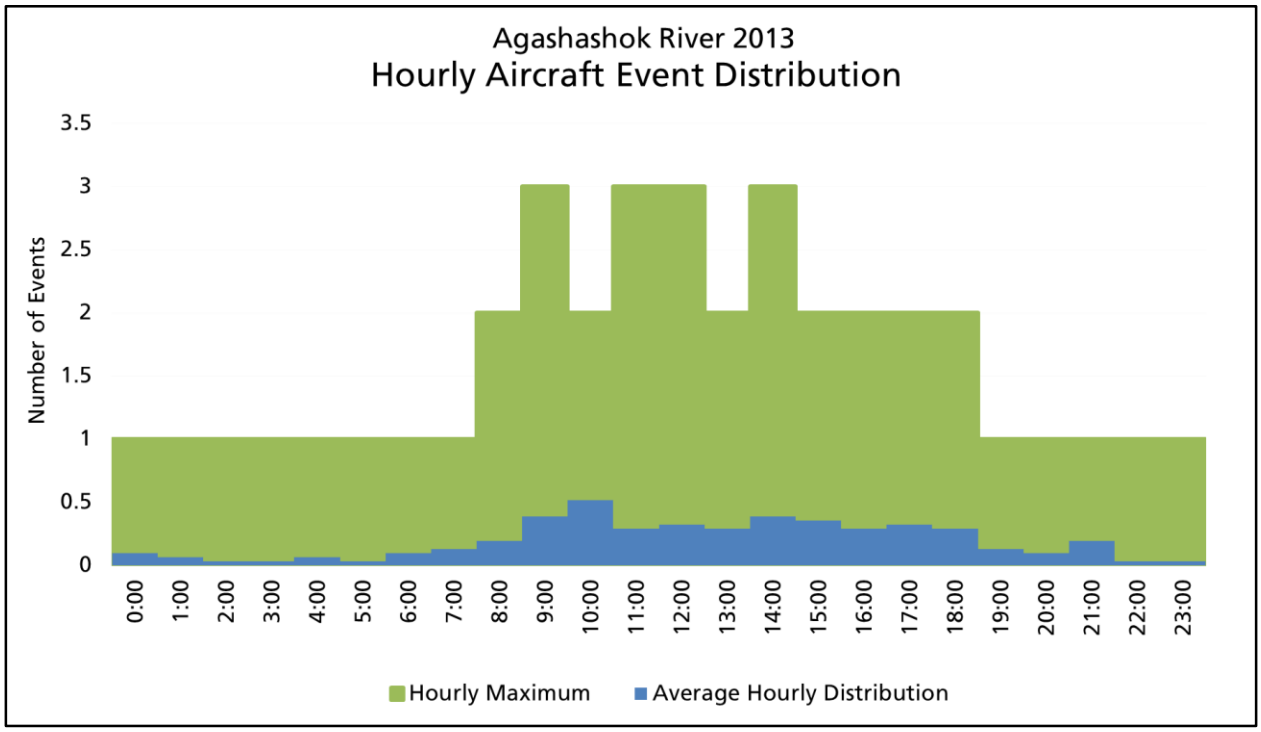


Figure 7. Hourly average and maximum rates of detection for aircraft noise events at Agashashok River, 2013.

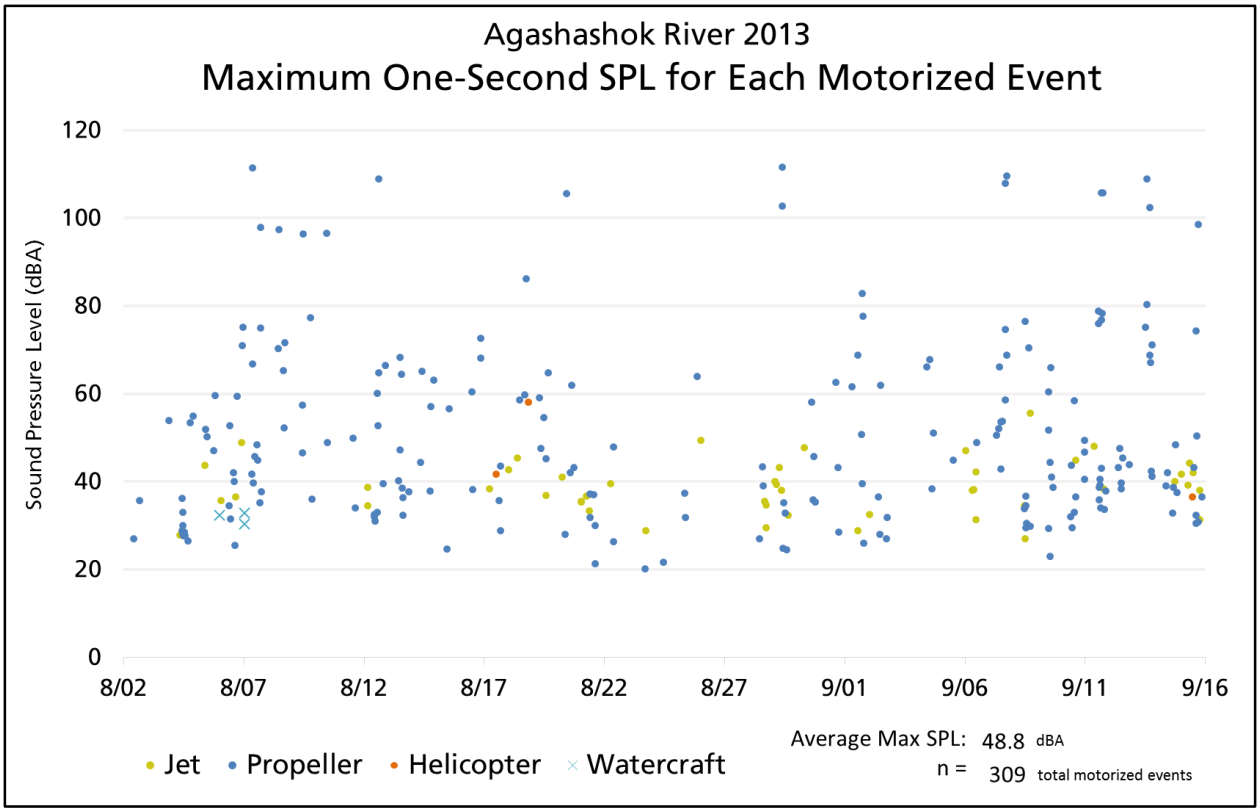


Figure 8. Maximum one-second sound pressure level for each aircraft event detected at Agashashok River, 2013.

Kugururok River, 2013

Location Description: On the floodplain of the Noatak River near its confluence with the Kugururok River 25 miles upriver of the western boundary of the preserve, and approximately 140 meters north of the main stem of the Noatak River.

Purpose/Project: The purpose of this project was to collect preliminary natural soundscape data in Noatak National Preserve, and to quantify the acoustic impact of both aircraft and motorboats at a place and time affected by both the ADF&G and NPS aircraft controlled-use areas. In 2013, this site only ran through August, 25th, and thus captures only an early portion of the hunting season.

Coordinates: 67.96390°, -161.95822° (WGS84)

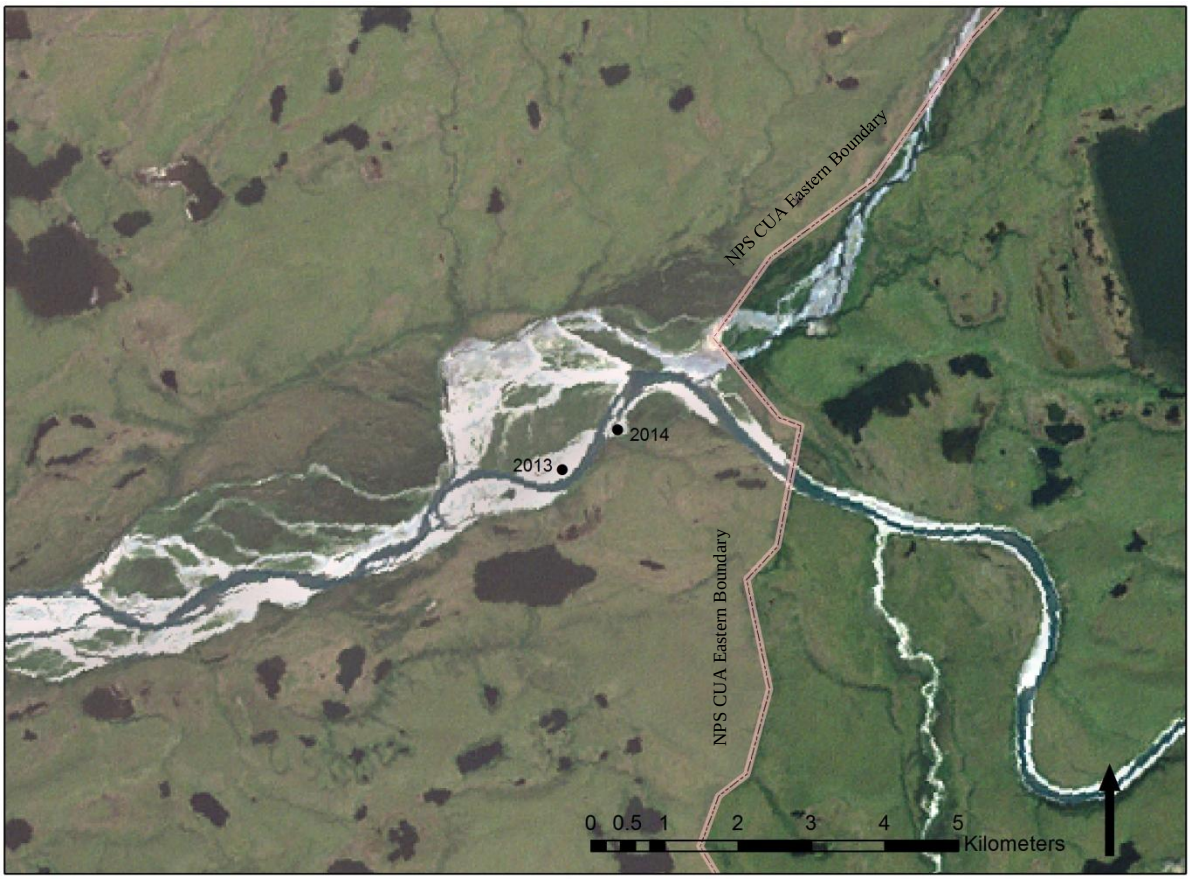
Elevation: 83 meters

Sampling Period: 02-August-2013 to 25-August-2013

Backcountry Management Area: inside both the NPS and ADF&G controlled-use areas. Designated Wilderness area.

Ecotypes: Sparse Vegetation

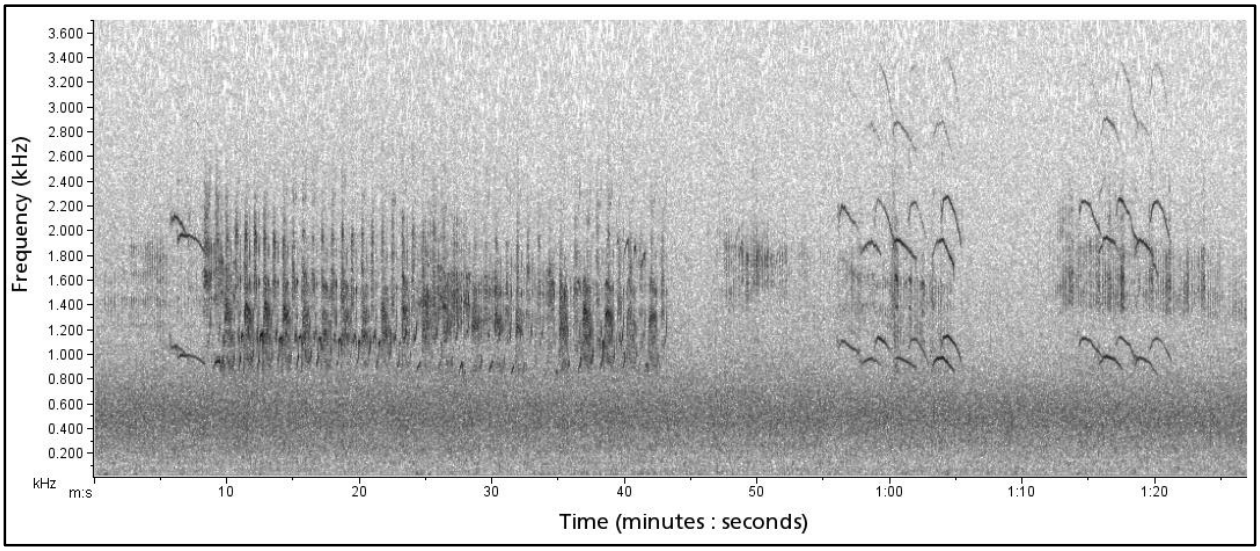
Access: Cessna 206 on wheels. Curtis Cebulski pilot, Andrew Ackerman and Marci Johnson technicians.



Summary: The riparian soundscape in the vicinity of the Kugururok River site had a time-averaged natural ambient level of 26.3 dBA. Even more so than the Agashashok River site, proximity to energetic water made broadband sound pressure levels relatively constant, as can be seen in Figure 9. In fact, diurnal cycles in the broadband natural ambience are notably absent. Also apparent from Figure 9 is a relatively large separation between L90 and L10 during the morning hours. This difference is likely driven by strong winds that occurred throughout the sampling period. The median hourly windspeed was 1.9 m/s, with a maximum hourly windspeed of 6.0 m/s observed.

In 2013, data from the Kugururok River site were only collected for the month of August before power was lost. (Bear damage terminated the record on 08/19/13 at 23:59:19.) For a large portion of the sampling period (08/03/13 – 08/14/13,) the ADFG Noatak CUA was open to landings for big game transport. However, for the entire sample period the NPS Delayed Entry Area, or all areas west of the Kugururok River and west of the Maiyumerak Mountains, was closed to commercially-transported caribou hunters. This means that during the first eleven days of the sample in August one would expect at this site a higher level of commercial-hunt related landing activity within the Noatak River corridor, especially non-local parties pursuing big game other than caribou. Human-caused noise was audible for 1.82% of this relatively early timeframe. No fixed-wing takeoffs nor landings were detected at the site, nor were any watercraft detected. Aircraft overflights occurred at a rate of 4.2 per day. The median level of aircraft at their loudest was 45.6 ± 14.1 dBA, well above the ambient sound pressure level.

The most prominent natural sound sources at the Kugururok River site were abiotic, with flowing water and wind both audible for a large part of the sampling period. Biotically, commonly detected species included Red-throated Loon (*Gavia stellata*), Northern Raven (*Corvus corax*), Sandhill Crane (*Grus canadensis*), and Red Breasted Merganser (*Mergus serrator*).



Spectrogram 2. A pair of Red-throated Loons (Gavia stellata) call to each other in antiphony. The clip begins at 18:43:44 on 08/08/2013. Listen to this sound on xeno-canto, an avian sound website, at http://www.xeno-canto.org/156486

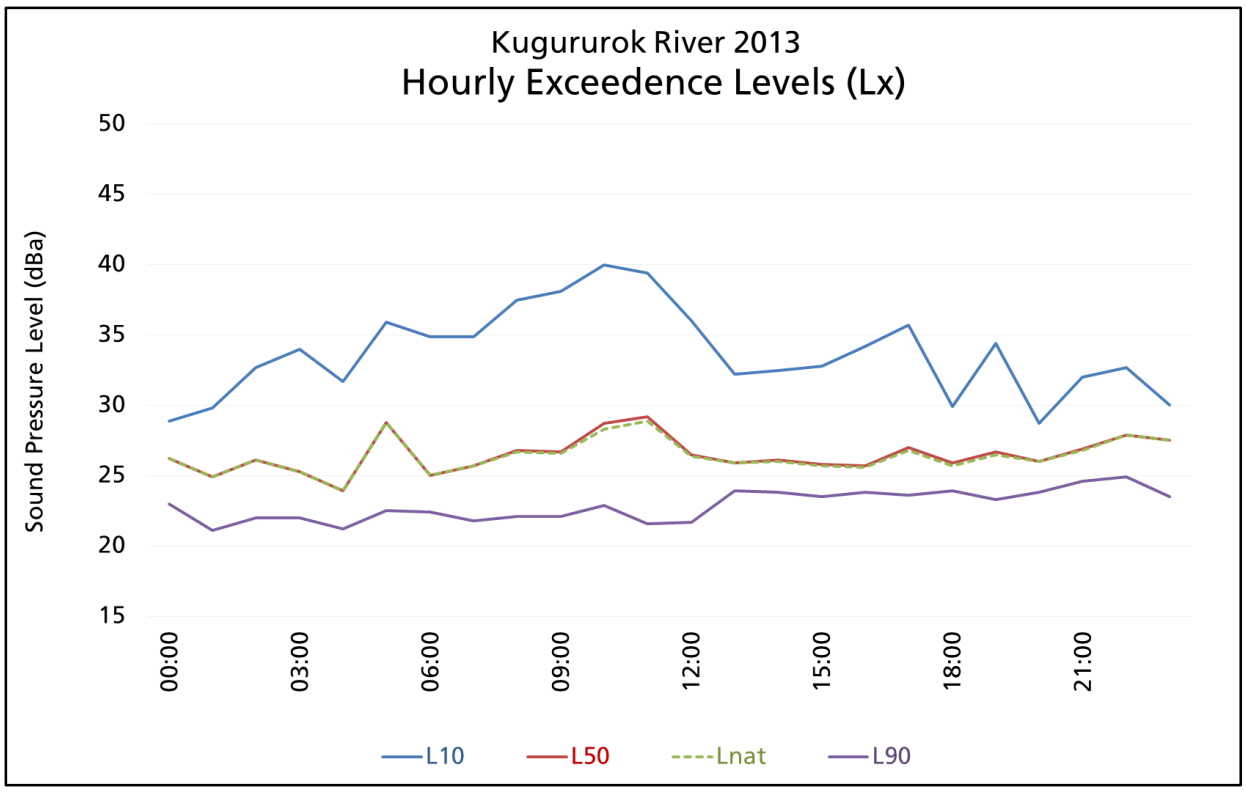


Figure 9. Exceedence levels for Kugururok River, 2014.

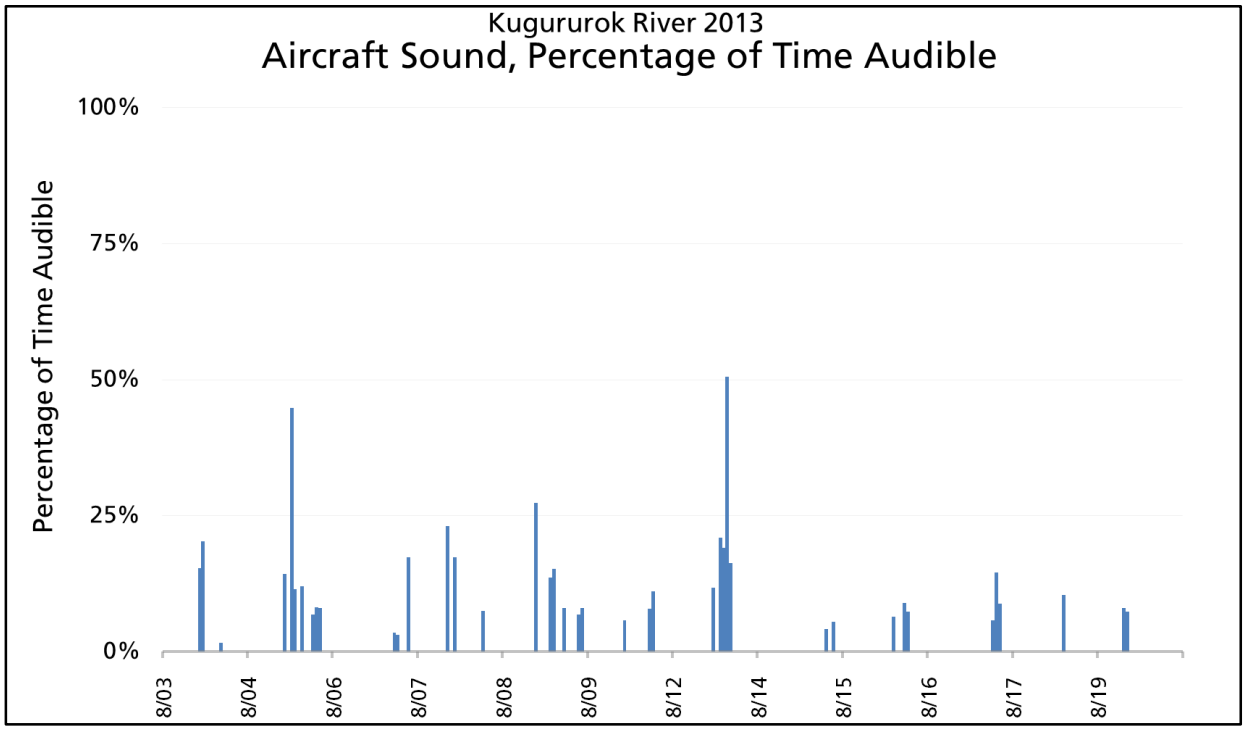


Figure 10. Audibility of aircraft noise by hour at Kugururok River, 2013.

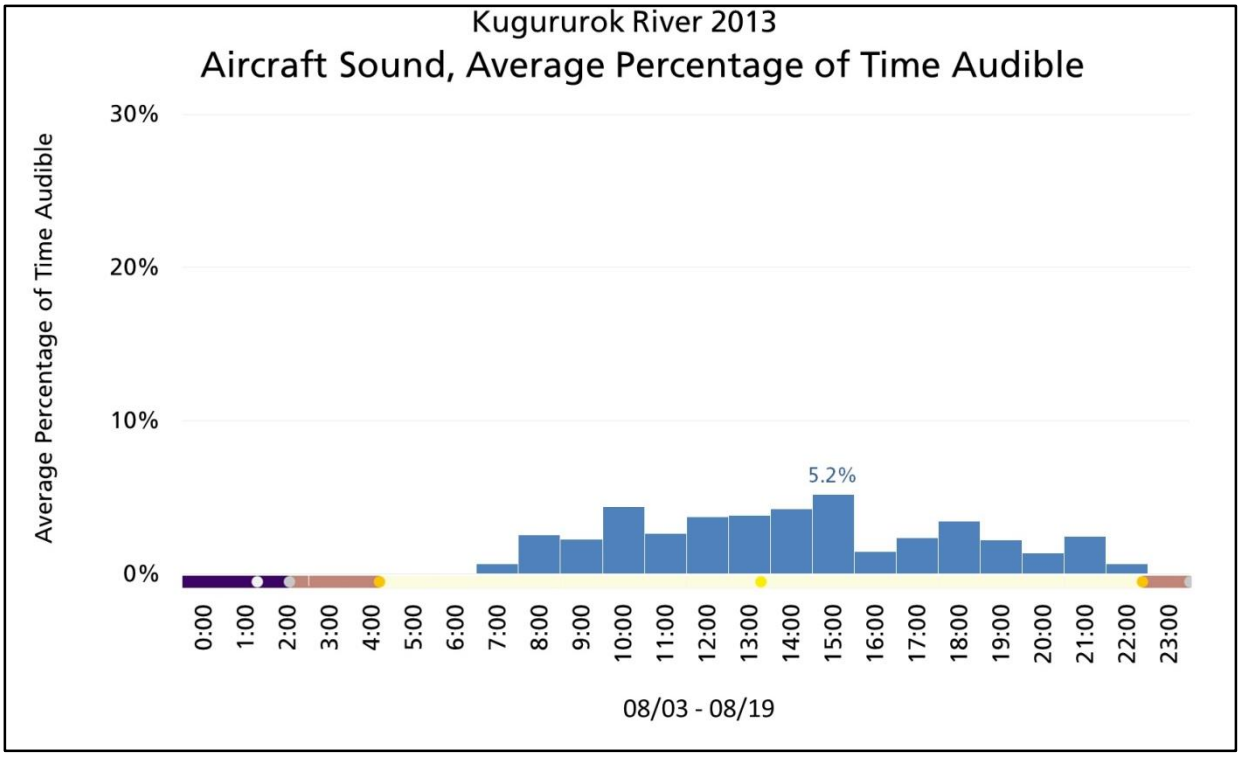


Figure 11. Audibility of aircraft noise for an average day, by hour, at Kugururok River, 2013. The bar along the time axis indicates the average light conditions during the sampling period. The orange circles are sunrise/sunset, and the gray circles are the beginning and end of civil twilight.

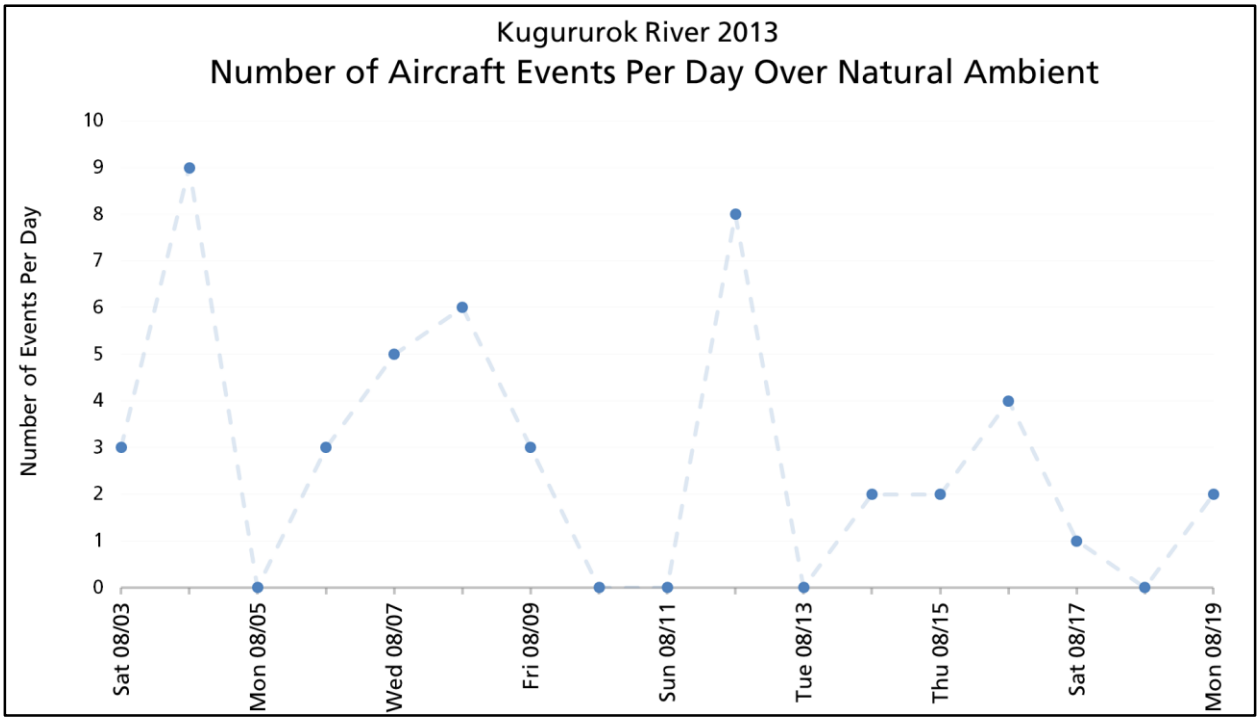


Figure 12. Number of aircraft noise events detected per day at Kugururok River, 2013.

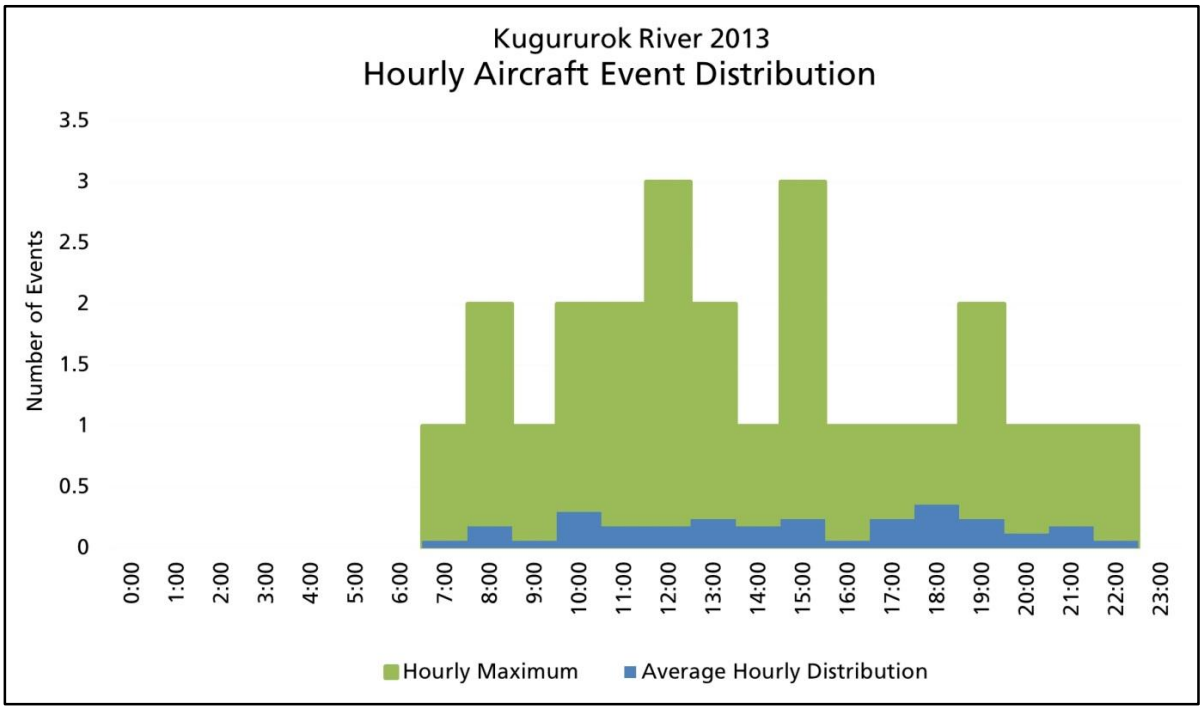


Figure 13. Hourly average and maximum rates of detection for aircraft noise events at Kugururok River, 2013.

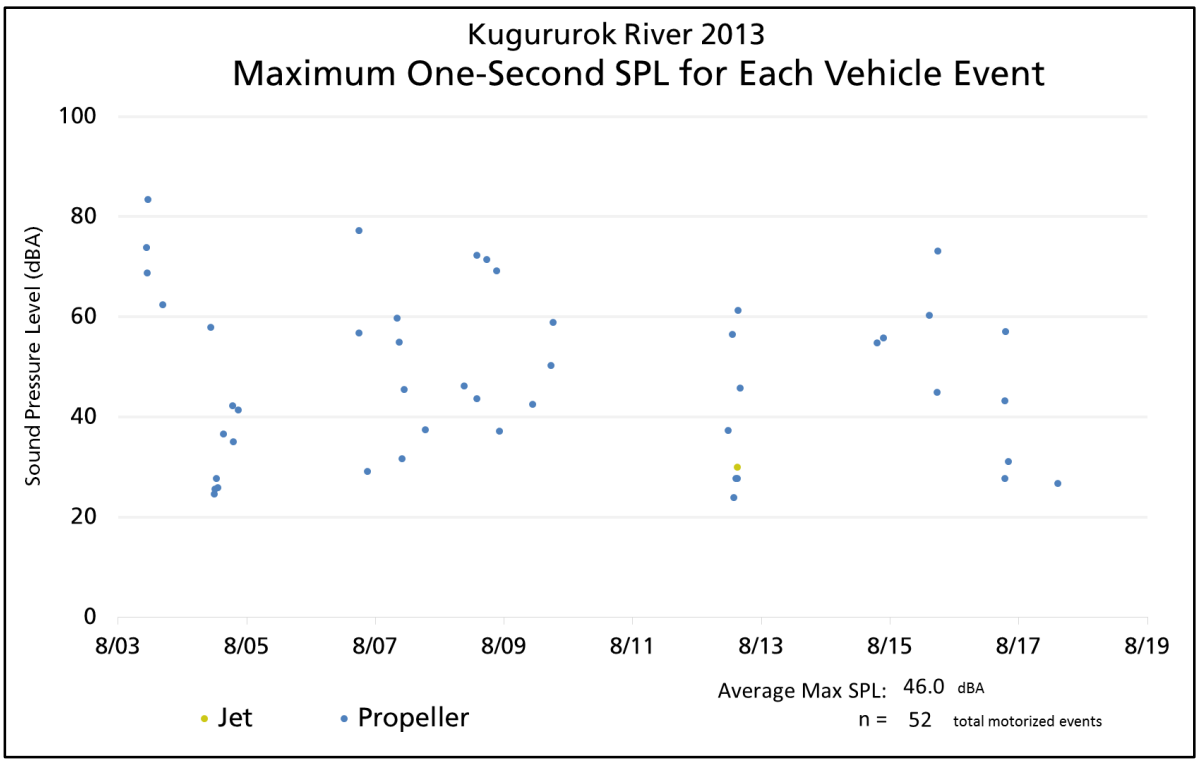


Figure 14. Maximum one-second sound pressure level for each aircraft event detected at Kugururok River, 2013.

Kugururok River, 2014

Location Description: Located on a low terrace of the Noatak River, approximately 114 meters from the southern bank. The site location appears to have been a former channel of a tributary stream.

Purpose/Project: The purpose of this project was to collect preliminary natural soundscape data in Noatak National Preserve, and to quantify the acoustic impact of both aircraft and motorboats at a location within both the ADF&G and NPS controlled-use areas. In 2014, this site was sampled later in the hunting season to include peak season traffic.

Coordinates: 67.97138°, -161.93248° (WGS84)

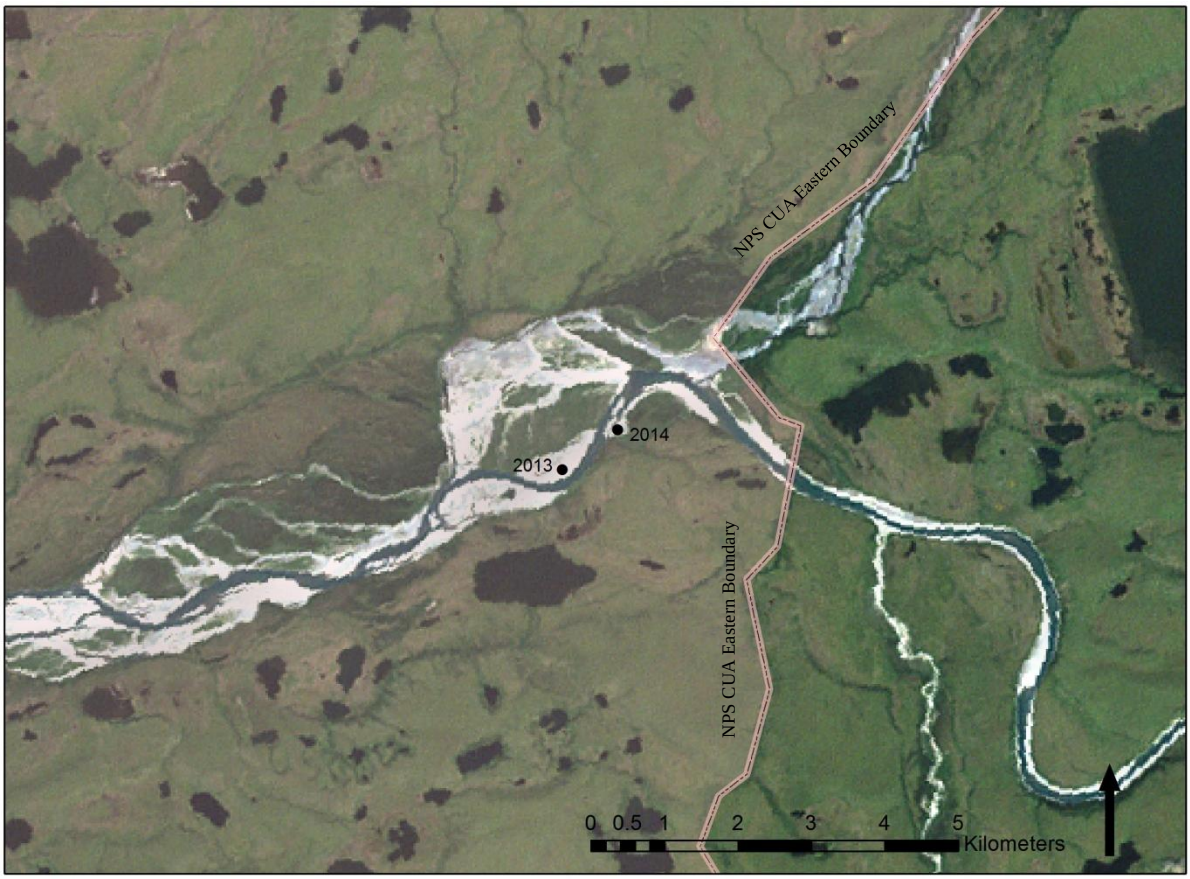
Elevation: 81 meters

Sampling Period: 11-September-2014 to 01-October-2014

Backcountry Management Area: inside both the NPS and ADF&G controlled-use areas. Designated Wilderness area.

Ecotypes: Tall Shrub Willow; *Viereck class:* Open Tall Willow Scrub

Access: Cessna 206 on wheels. Curtis Cebulski pilot, Davyd Betchkal and Andrew Ackerman technicians.



Summary: An important note is that in 2014, the Kugururok River site had a different location and a different sampling period than in 2013. The 2014 sampling location was chosen to be more upland, away from the potential of flood or ice damage should the station be irretrievable in the fall or early winter. Furthermore, it was deemed necessary to sample at a time that adequately described hunting behavior. Mid-to-late September was a natural choice to capture hunting activity near the Noatak.

In 2014, the Kugururok River site had a time-averaged natural ambient level of 29.2 dBA. Similar to 2013, the 2014 site had a relatively time-invariant natural ambient level, as can be seen in Figure 15. Unlike 2013, however, the separation between L90 and L10 is relatively small, suggesting that the variation in acoustic levels was also small. In fact, windspeeds in 2014 were considerably lower, consistent with the hypothesis that periods of strong winds increased separation between L90 and L10 in 2013. The median hourly windspeed was 0.6 m/s, with a maximum hourly windspeed of 3.9 m/s observed. (Compare to median of 1.9 m/s, maximum of 6.0 m/s in 2013.)**Error! Reference source not found.**.

Figure 15. Exceedence levels for Kugururok River 2014.

Human-caused noise was audible for 4.13% of the sampling period. Aircraft were audible 1.76% of the sampling period and boats were audible 3.20% of the sampling period. (Note that 1.76% + 3.20% ≠ 4.13%, because boats and aircraft were sometimes heard at the same time.) A fairly high rate of boat traffic was observed, at 5.1 events per day. No fixed-wing takeoffs nor landings were detected at the site. Aircraft overflights occurred at a rate of 3.7 per day, less than the detection rate in 2013.

(Note that acoustic detection rates are affected by the natural ambient level. The 2014 site had a time-averaged natural ambient level that was 3.0 dBA louder than in 2013. This equates to about a 50% reduction in listening area between the two locations, which is one explanation for the reduced detection rate. For a full description of this phenomenon and the equation used to calculate listening area reduction, see Barber 2010, pg. 183.) Notably, more boat noise events were audible on a typical day than aircraft events. Boats also had a longer median duration (7.1 minutes) than aircraft (5.8 minutes) at the site. Altogether, this made boat noise audible about twice the amount of time that aircraft noise was audible. Typical sound pressure levels of watercraft and aircraft were comparable, however. Median levels (plus or minus median absolute deviation) at their loudest were 45.35 ± 5.8 dBA and 43.8 ± 7.0 dBA for boats and aircraft, respectively. Maximum levels, on the other hand, were not similar. The loudest level measured for aircraft was 75.8 dBA, but 59.9 dBA for boats.

Similar to its predecessor, the Kugururok River site in 2014 was predominated by the sounds of flowing water and wind. However, due to a damaged flash card, no audio record was recorded for the site, and thus no record of common biological sounds has been compiled.

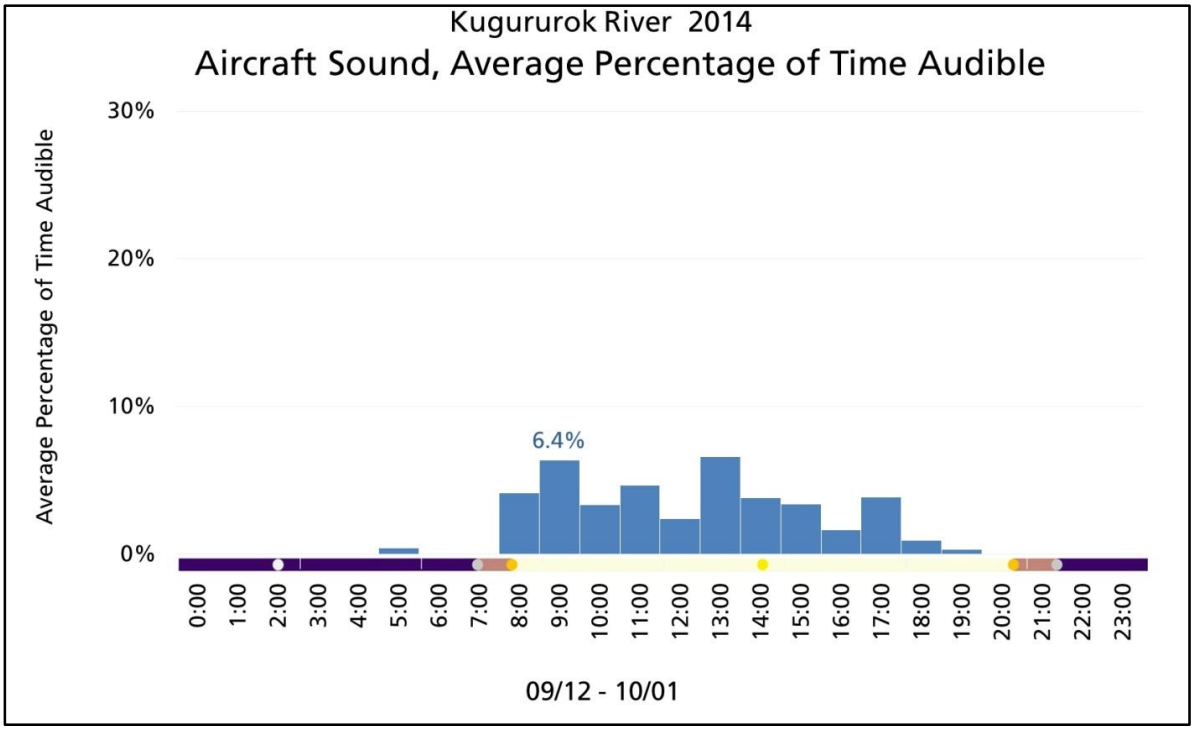


Figure 15. Audibility of aircraft noise for an average day, by hour, at Kugururok River, 2014. The bar along the time axis indicates the average light conditions during the sampling period. The orange circles are sunrise/sunset, and the gray circles are the beginning and end of civil twilight.

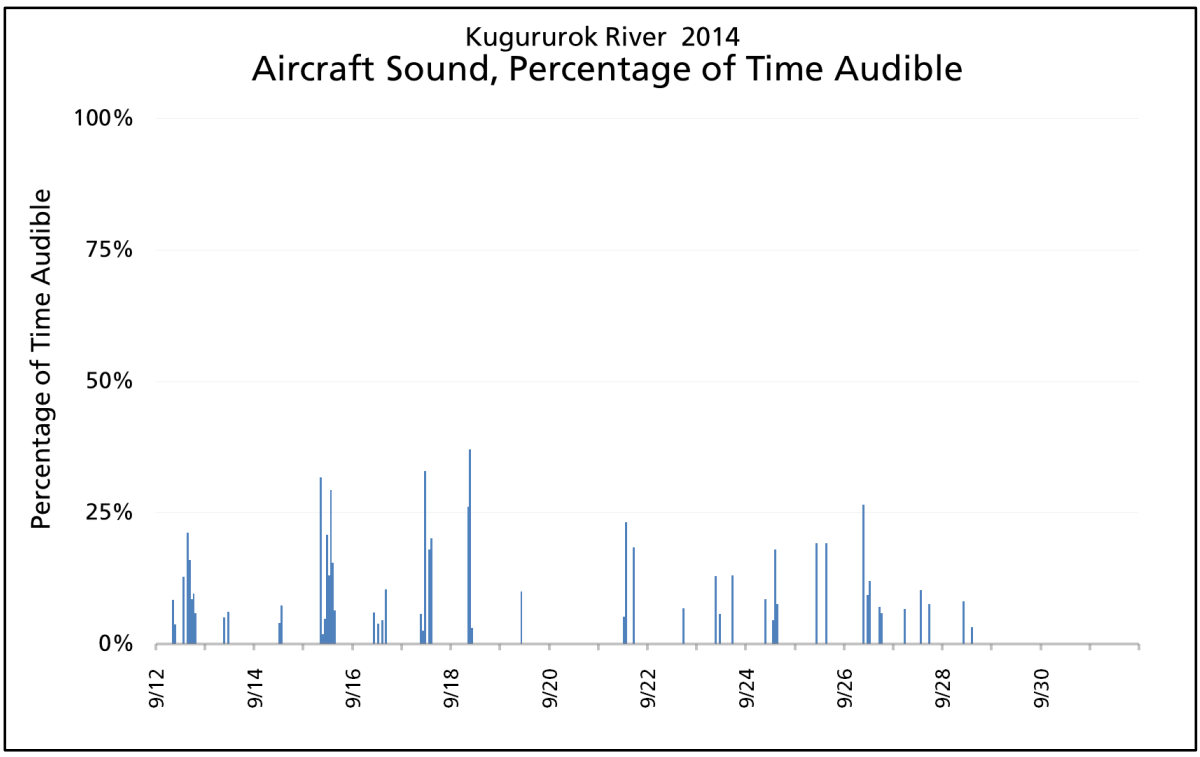


Figure 16. Audibility of aircraft noise at Kugururok River, 2014.

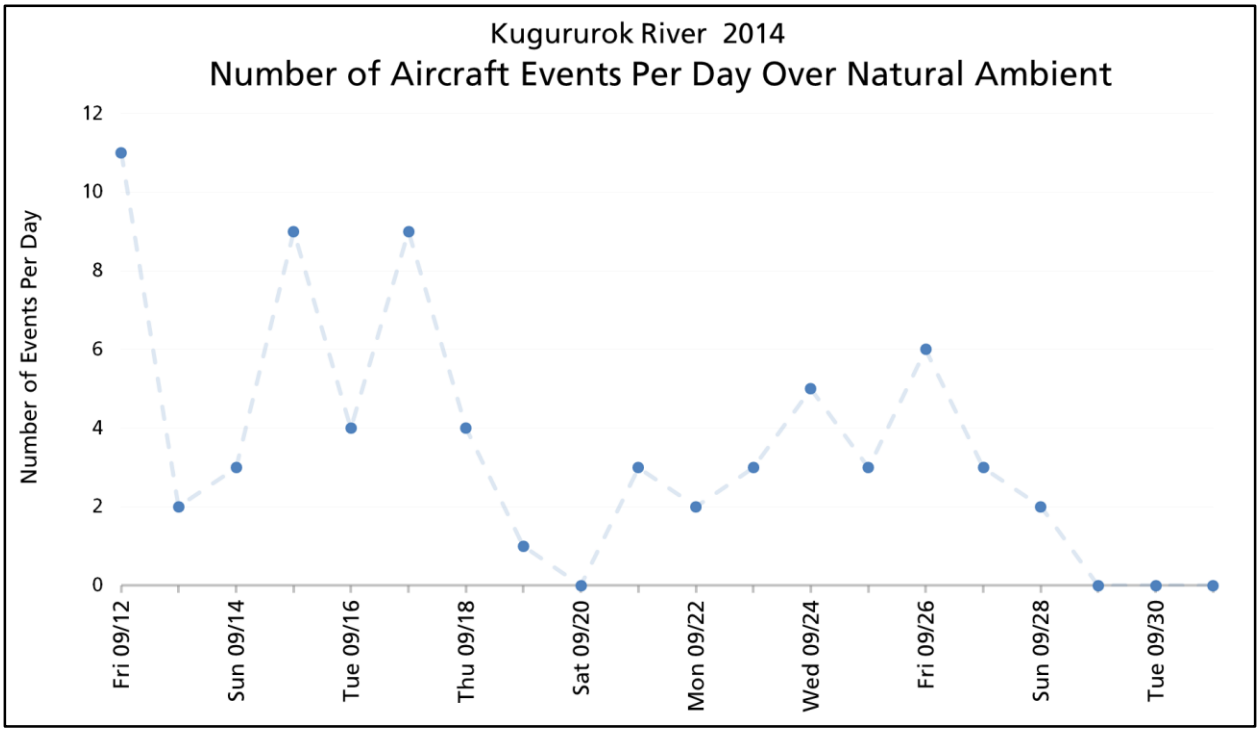


Figure 17. Number of aircraft noise events detected per day at Kugururok River, 2014.

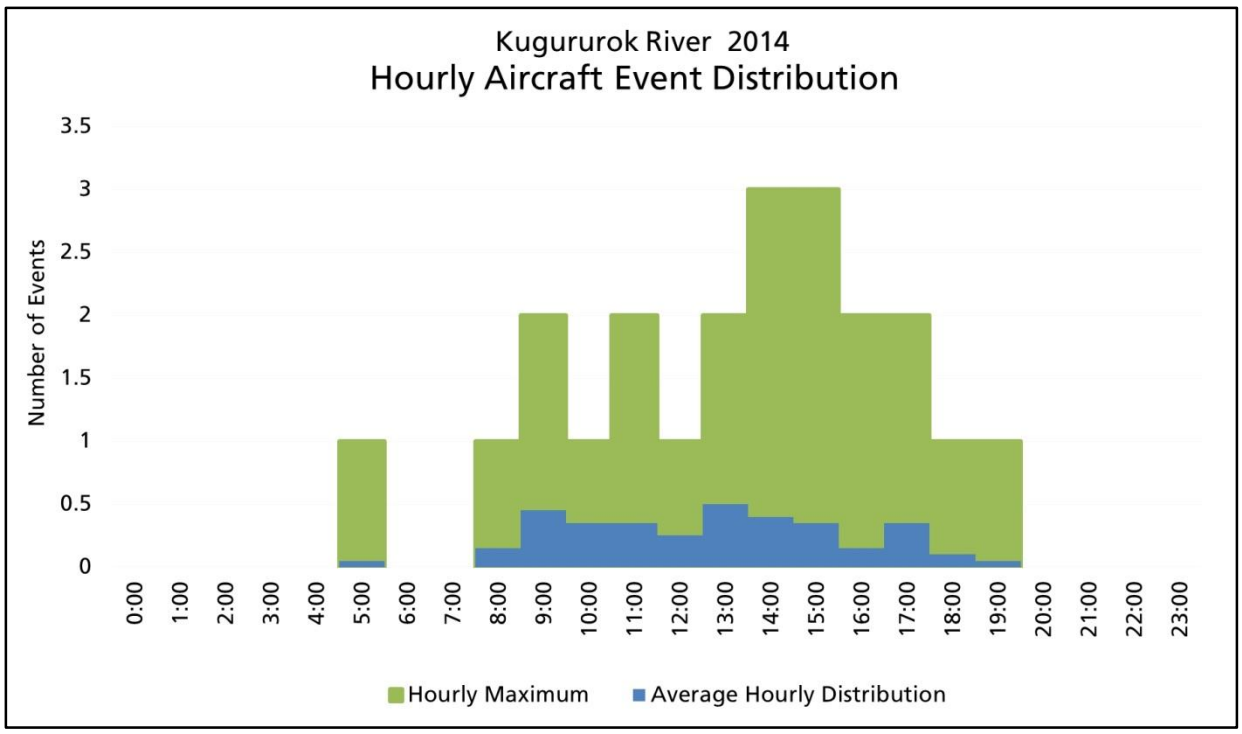


Figure 18. Hourly average and maximum rates of detection for aircraft noise events at Kugururok River, 2014.

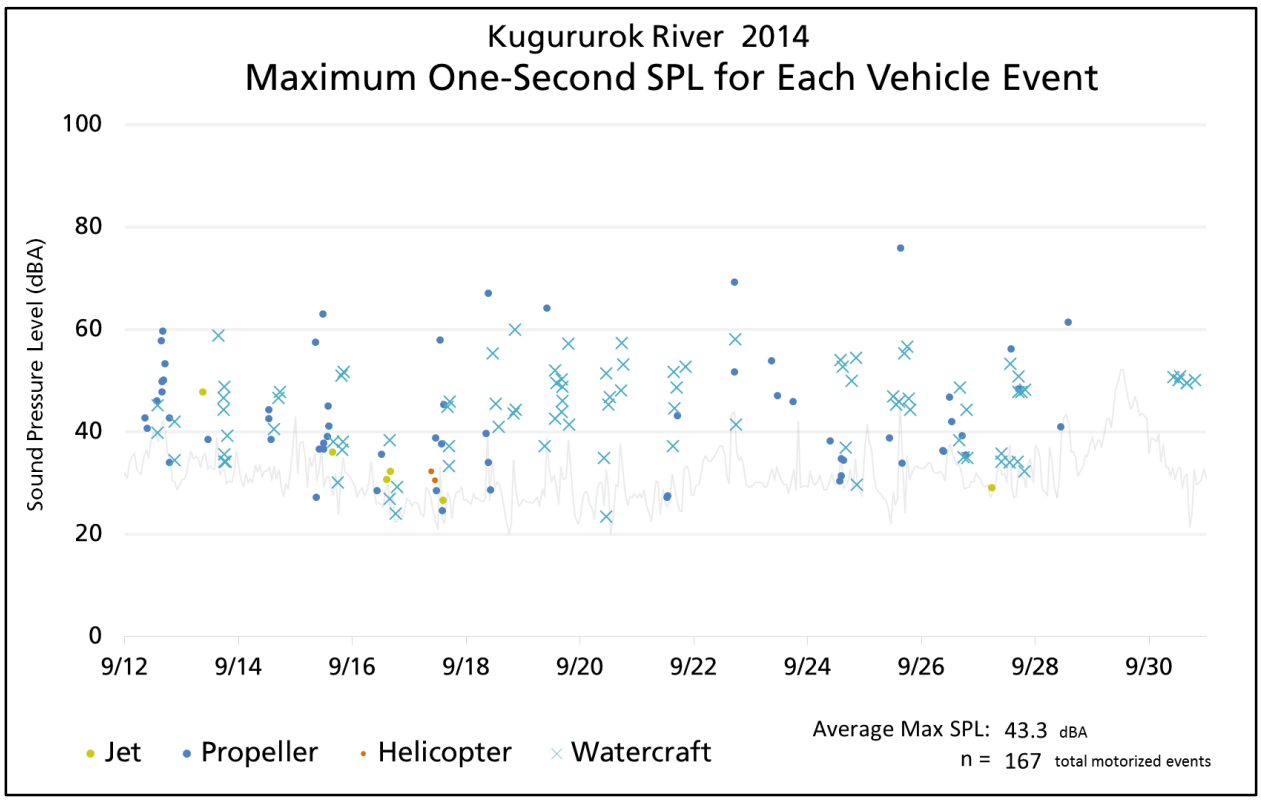


Figure 19. Maximum one-second sound pressure level for each aircraft event detected at Kugururok River, 2014.

Sapun Creek, 2014

Location Description: Located on a terrace above the immediate floodplain of the Noatak River, approximately 213 meters from the southern bank. Site was located about 67 meters north of a higher floodplain terrace, as can be seen in the background of the site photograph. A small seasonal pond was located between the microphone and this terrace.

Purpose/Project: The purpose of this project was to collect preliminary natural soundscape data in Noatak National Preserve, and to quantify the acoustic impact of both aircraft and motorboats on the river just outside of the ADF&G controlled-use area. This site was sampled later in the hunting season.

Coordinates: 67.90017°, -160.34048° (WGS84)

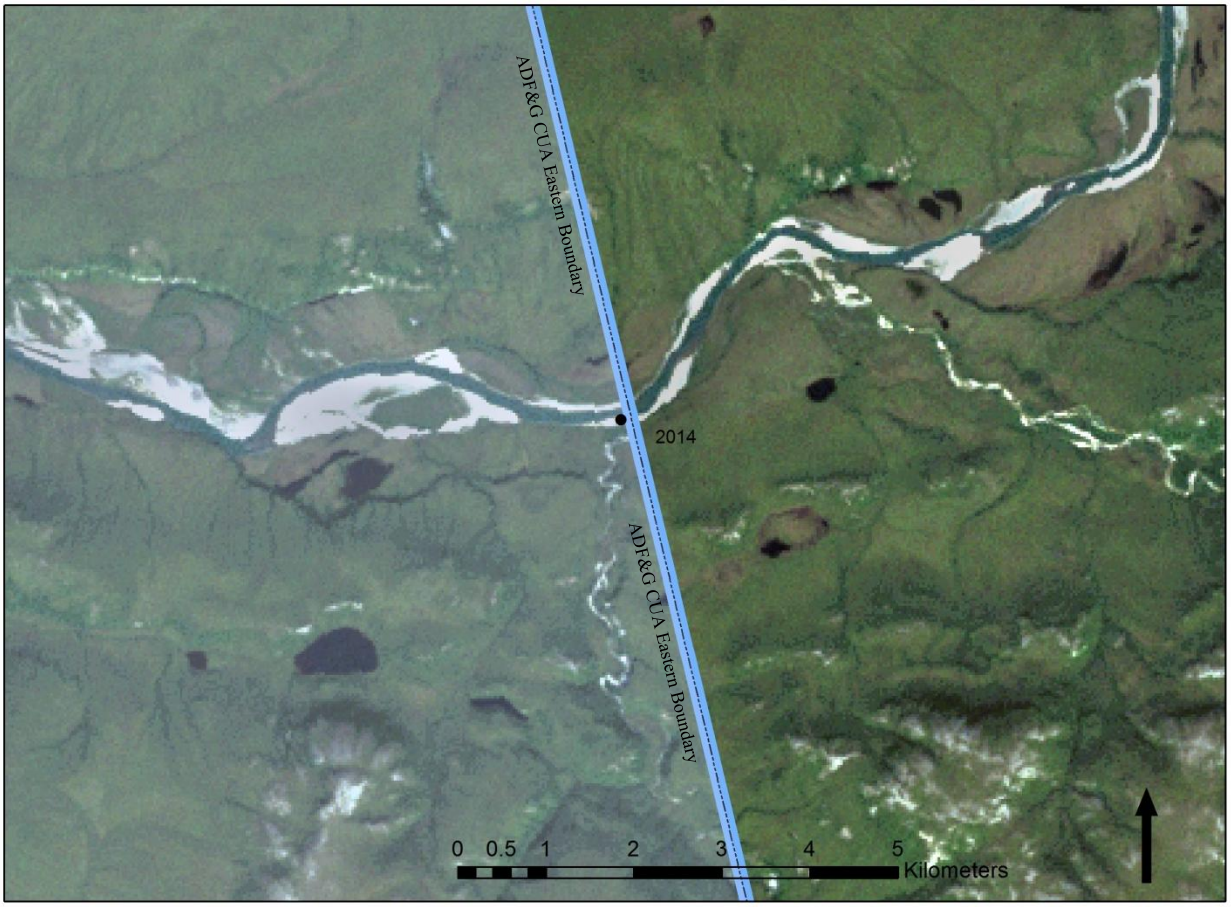
Elevation: 159 meters

Sampling Period: 11-September-2014 to 01-October-2014

Backcountry Management Area: on the boundary of the ADF&G controlled-use area. Designated Wilderness area.

Ecotypes: Willow Shrub, Open Low Shrub Sedge; *Viereck classes:* Open Low Willow Shrub, Open Tall Willow Shrub

Access: Cessna 206 on wheels. Curtis Cebulski / Dan Sheldon pilots, Davyd Betchkal and Andrew Ackerman technicians.



Summary: The Sapun Creek site had a time-averaged natural ambient level of 28.6 dBA. Similar to all the riparian sites sampled in Noatak thus far, Sapun Creek had a relatively time-invariant natural ambient level, as can be seen in Figure 20. A slight diurnal decrease in levels is also apparent in the graph, an effect likely caused by changes in the refractive qualities of the atmospheric media.

Human-caused noise was audible for 3.26% of the sampling period. Aircraft were audible 2.87% of the sampling period and boats were audible 0.97% of the sampling period. Upstream approximately 57 river miles from the Kugurorok River site, the detection rate of watercraft at Sapun Creek was of 1.4 events per day. (Compare to 5.1 at Kugururok River.) Median levels for boats (plus or minus median absolute deviation) at their loudest were 42.2 ± 5.5 dBA.

Identification of boats was aided by looking for the sweeping frequency shifts typical of boats. Boats could be differentiated from aircraft by seeking out this 'warbling' signal. Boat signatures generally had two components – one tonal, and one broadband. During steady, cruising conditions, the tonal component was a harmonic series with prominent energy in the 31.5, 50, and 125 Hz bands. The broadband component of a typical watercraft signal was composed of diffuse energy with bounds in the 20 Hz and 6300 Hz bands. There was also a considerable drop in energy above the 400 Hz band. Furthermore, the onset and decay of the noise signals could be used to differentiate vehicle types. Upon takeoff, fixed-wing aircraft have a spectrally-broad, energetic powerup that is usually associated with a long-duration, low-pitched onset while the pilot preforms their pre-flight checks.

Boats, on the other hand, have a sudden, but spectrally narrow increase to full power. When powering down, boats emit a chugging, variable-frequency 'warbling' sound. Aircraft engines, however, almost immediately silence, unless they are taxiing, in which case the sound is low-amplitude and continuous.

Fixed-wing aircraft landings were detected on 09/23/14 and 09/26/14, with takeoffs occurring shortly afterwards. Obviously, these four operations were only a small component of the 7.8 aircraft noise events detected on an average day. For aircraft, median levels (plus-or-minus the median absolute deviation,) were 48.0 ± 7.6 dBA, comparable to the median levels for boats. Maximum levels, on the other hand, were not similar. The loudest level measured for aircraft was 98.9 dBA, but 58.3 dBA for boats. A minor but notable sound source during the record was gunshots. They were detected on a single occasion – 09/22/14, during the 17:00 hour.

Like many of the riparian soundscapes documented thus far in Noatak, the Sapun Creek site was predominated by the sounds of flowing water and wind. However, audio at the site was corrupted shortly after install, allowing only superficial, hollow-sounding playback of sources. Because of this, only loud sources were audible, and then only with a considerable amount of coloration of the signal. Despite poor quality audio, Redpoll spp. and Willow Ptarmigan (*Lagopus lagopus*) were detected during the sampling period.

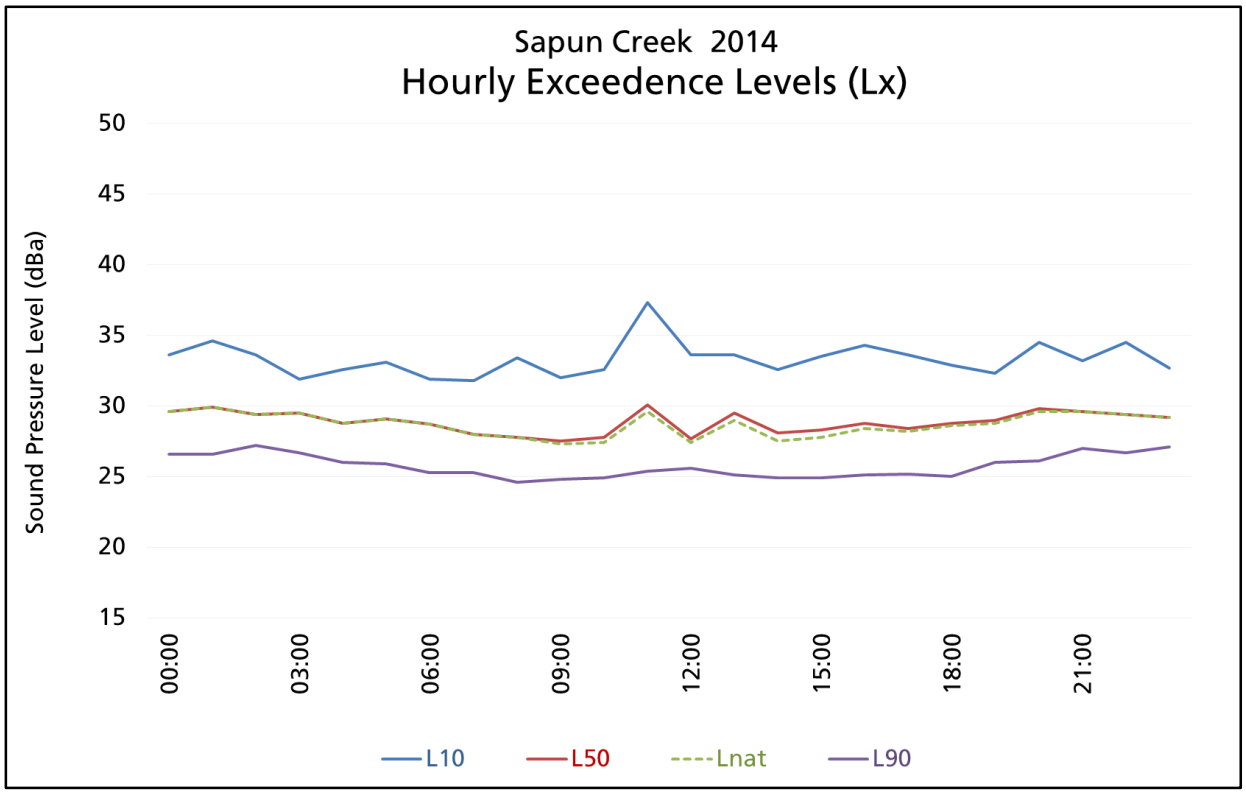


Figure 20. Exceedence levels for Sapun Creek, 2014.

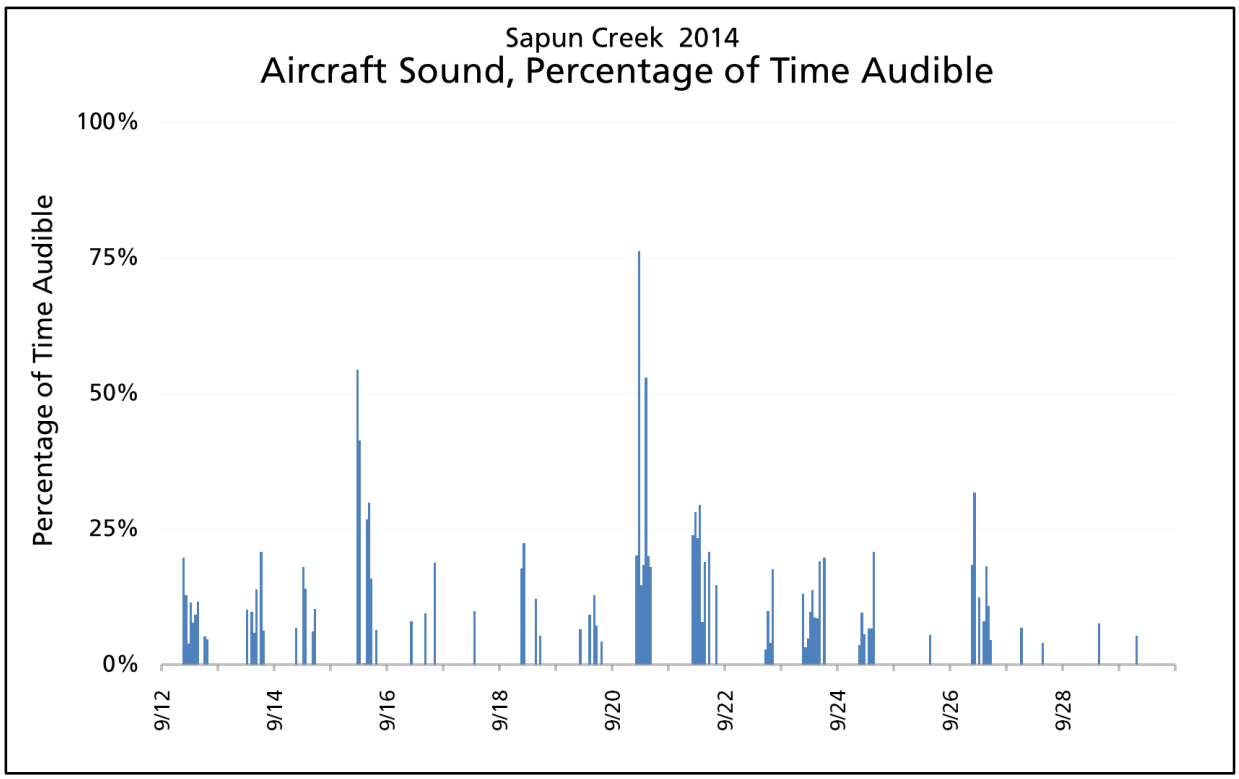


Figure 21. Audibility of aircraft noise by hour at Sapun Creek, 2014.

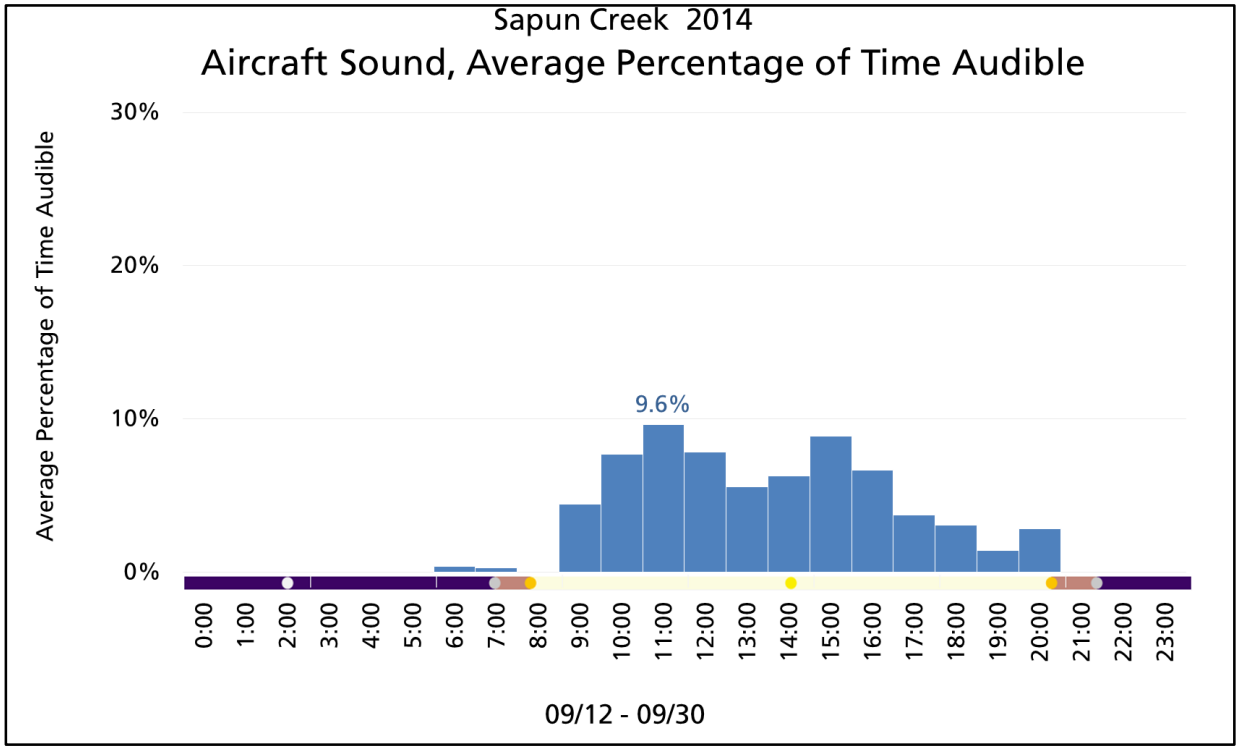


Figure 22. Audibility of aircraft noise for an average day, by hour, at Sapun Creek, 2014. The bar along the time axis indicates the average light conditions during the sampling period. The orange circles are sunrise/sunset, and the gray circles are the beginning and end of civil twilight.

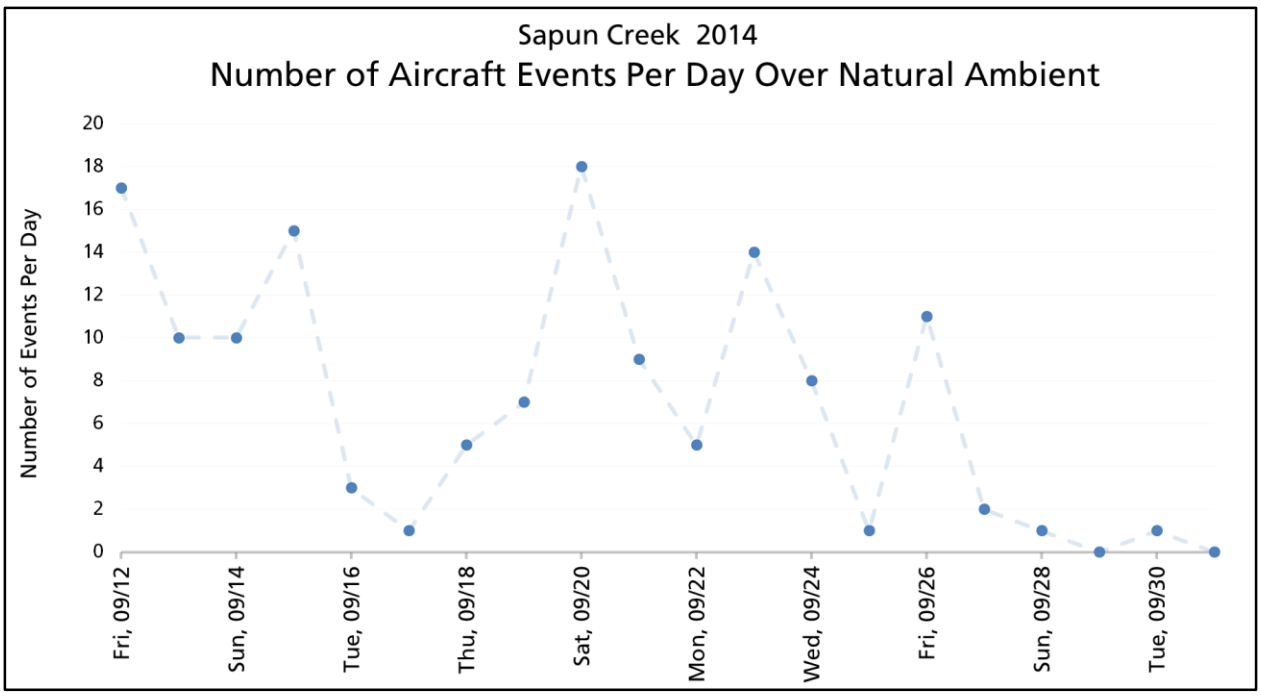


Figure 23. Number of aircraft noise events detected per day at Sapun Creek, 2014.

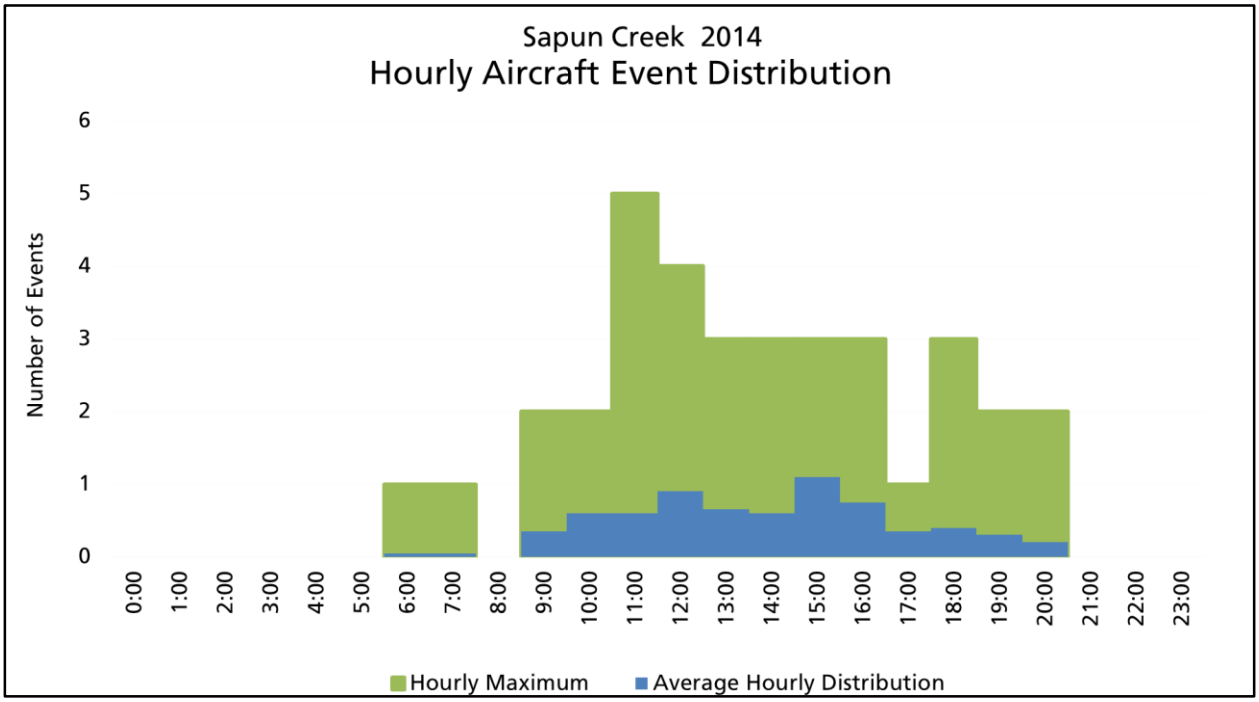


Figure 24. Hourly average and maximum rates of detection for aircraft noise events at Sapun Creek, 2014.

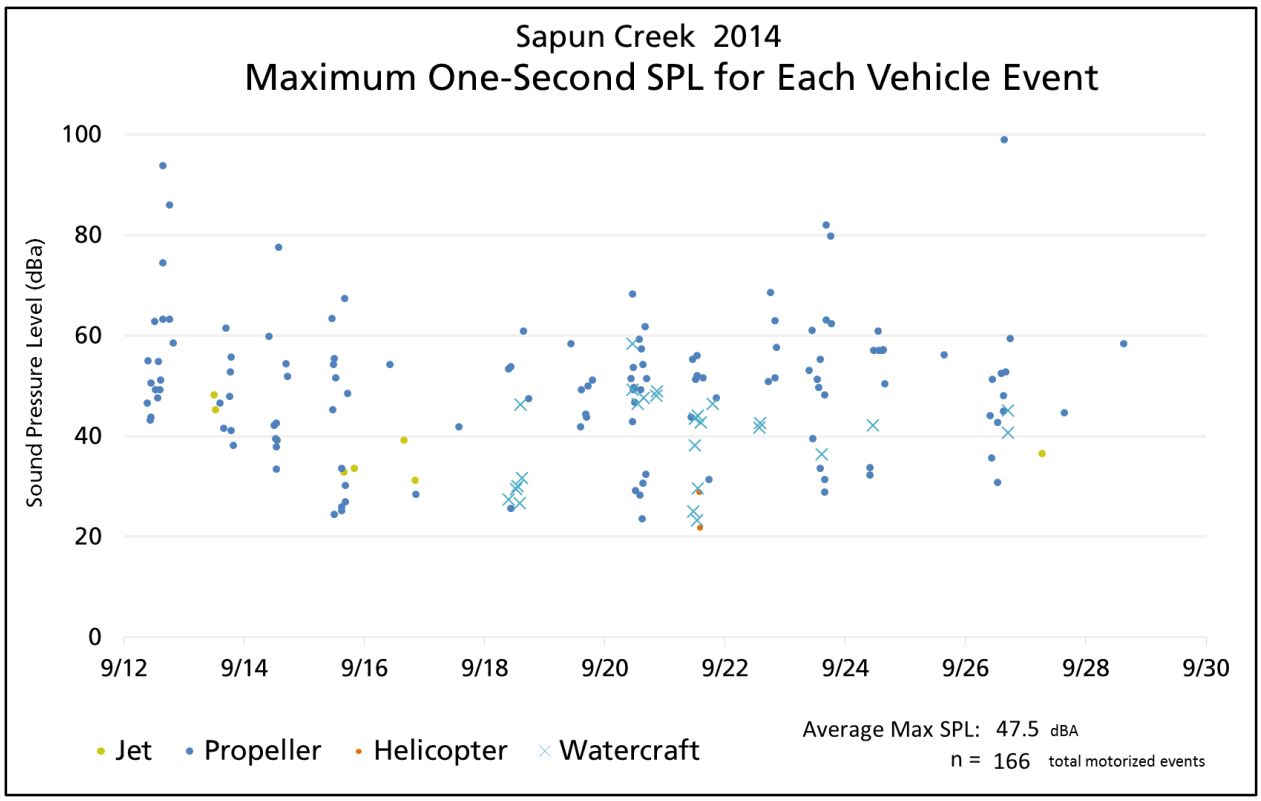


Figure 25. Maximum one-second sound pressure level for each aircraft event detected at Sapun Creek, 2014.

Conclusions and Future Work

The results from this study present current information on the acoustic environment at three sites in Noatak National Preserve. All of these were within close proximity to rivers, and thus had similar acoustics. Continuous flowing water was the main contributor to broadband sound pressure levels. As such, the range of natural ambient levels observed was also relatively small – from 26.3 dBA at the Kugururok River site in 2013 to 30.3 dBA at the Agashashok River site in 2013, a difference of about 4 dBA.

Spatially, these acoustic data represent the western Noatak River and the Agashashok River drainage. In these areas, the data allow the park to monitor change in motorized use patterns over time. Additional preemptive benefit could be gained by adding acoustic monitoring sites in the eastern portion of the preserve. Such a design anticipates changes in noise condition if the Western Arctic Caribou herd shifts migration routes from easterly to westerly. If aircraft tend to follow the herd, this would cause noise conditions to degrade within the western CUA areas while improving in the more remote eastern areas. Without sampling in the east, the park would only be able to detect a localized increase in western traffic.

Furthermore, monitoring during other seasons would provide context for acoustic conditions during the fall hunting season. Summer measurements would allow a broader knowledge of natural variability, document more typical human noise levels, and provide the potential for a thorough study of avian biodiversity. Measuring impacts due to snowmachine use would require sampling during the winter or spring.

During future monitoring phases, it is important to remember that the remoteness of Noatak prohibits repeated site maintenance trips. A successful approach for future sampling in the preserve could be to deploy stations with very large battery and solar panel banks, and come back to retrieve them several months later. Such a scenario is only acceptable if the cost of access outweighs the cost of lost data due to wildlife disturbance. It was also found that with appropriate coordinates and site photographs, NPS ranger pilots could retrieve the equipment on their own. Combining such a removal flight with other patrol duties would further reduce the cost of monitoring efforts.

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